COMPARATIVE RESPONSE OF *EOCANTHECONA FURCELLATA* (WOLFF) AND *PODISUS MACULIVENTRIS* (SAY) TO TEMPERATURE AND PHOTOPERIOD AND THEIR RELATIVE POTENTIAL AS BENEFICIAL PREDATORS

BY

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by
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DEDICATION

To my father, Mr. W. S. Tseng, and my mother, Mrs. Y. C. Huang Tseng, for their love, patience, encouragement, and understanding.

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Abstract of Dissertation Presented to the Graduate Council of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

COMPARATIVE RESPONSE OF EOCANTHECONA FURCELLATA (WOLFF) AND PODISUS MACULIVENTRIS (SAY) TO TEMPERATURE AND PHOTOPERIOD AND THEIR RELATIVE POTENTIAL AS BENEFICIAL PREDATORS

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The development, fecundity, and longevity of two asopine species, Eocanthecona furcellata (Wolff) from Thailand and Podisus maculiventris (Say) from Florida, were studied under different conditions of temperature and photoperiod. Comparative data on the predatory efficacy of the two species against the velvetbean caterpillar, Anticarsia gemmatalis (Hubner), in soybean were obtained and evaluated. Methods were developed for mass rearing the two species and the greater wax moth, Galleria mellonella (L.), was used as factitious prey. The cost of labor and materials per 1000 asopine nymphs reared was approximately 96 cents.

E. furcellata was found to develop more rapidly and show highest fecundity when reared under long light (L:D 16:8) and at the highest of the three test temperatures,

18, 23, and 29°C. P. maculiventris performed best under long light at 23°C and much better than E. furcellata under short light (L:D 8:16) at the lower and intermediate temperatures. Nymphal development was delayed in both species when reared under short light conditions.

The inundative release experiment was designed to simulate the occurrence of a numerical response of a predator population to populations of the target host where the host population is maintained at non-economic levels. Although results of the inundative release experiment were positive, additional research is needed to determine optimal number and timing in order to obtain maximum benefits.

Based on production economics and field effectiveness, the 3rd instar of both species was found to be the most suitable stage for release against the velvetbean caterpillar. Best results were obtained when equal numbers of both predacious species were released together.

The velvetbean caterpillar population regularly peaks in late August when the average temperature is 27°C and day length is about 14 hrs. Laboratory data indicated that E. furcellata should have a decided competitive advantage over P. maculiventris under these climatic conditions but would be at a competitive disadvantage under north Florida fall, winter and spring conditions.

CHAPTER ONE
INTRODUCTION

Despite their now generally recognized problems, chemical pesticides remain the most effective method of controlling insect pest populations that, if not controlled, will cause an intolerable crop loss (DeBach, 1964; Huffaker, 1971). At the same time, most pest management research is directed toward methods that will minimize the use of chemical pesticides (van den Bosch, 1971; Knipling, 1979).

Because of the need to reduce production costs, and because of an awareness of the negative aspects of chemical pesticides, most growers would welcome any alternative method of pest control that would be cost competitive with chemicals (DeBach, 1964).

Of the various alternatives to chemical pest control, the use of natural enemies holds the most promise of avoiding many of the problems associated with chemicals. Biological control through importation of natural enemies has been highly effective against many insect pests and weeds (Bartlett and van den Bosch, 1964; DeBach, 1971; Freeman, 1976; Clausen, 1978; Papavizas, 1981; Ridgway and Ables, 1981). These pests, for the most part, have been species foreign to the areas where they cause a problem.

By returning to the native area of these species, entomologists have found their specialized enemies and colonized them in the invaded land area. While highly successful against a number of insect pests and weeds and causing some reduction of other pest problems, this method has been ineffective against many of the pests that have the greatest impact on agricultural production. Among the pests included in this category are the corn earworm, Heliothis zea (Boddie), the cotton boll weevil, Anthonomus grandis Boheman, and the codling moth, Laspeyresia pomonella (L.). Another such species is the velvetbean caterpillar, Anticarsia gemmatalis Hubner, which serves as a subject of this study.

While it cannot be said with certainty that no consistently effective self-perpetuating natural enemy will ever be found, none is available at this time. However, while biological control through importation of natural enemies does not appear to offer great promise against this pest, there are other methods by which natural enemies may be used in its management. One of these methods is augmentation of natural biological control through mass production of a suitable enemy species and periodic releases of stock into a threatened soybean crop. Depending on the kind of crop, the characteristics of the pest to be controlled, and if control is to be the result of the released enemy stock or their progeny, augmentive releases may be inundative or inoculative.

In the case of velvetbean caterpillar on soybean, outbreak populations develop with great rapidity. The ideal biological control would be one directed toward control of the pest in the egg stage. Eggs of the velvetbean caterpillar are readily attacked by egg parasites of the genus Trichogramma. While insect eggs of many orders serve as hosts for one or more species of Trichogramma, most are associated with Lepidoptera (DeBach, 1964; Stinner et al., 1974; Morrison et al., 1976). In view of the ability of Trichogramma to destroy the host before it hatches and thus avoid any injury to the crop plant, most research directed toward control of pests through augmentation of natural enemy activity has involved that genus. Trichogramma is being used to control such pests as the imported cabbage worm, Pieris rapae (L.), the codling moth, Laspeyresia pomonella (L.), oriental fruit moth, Grapholitha molesta (Busck), sugarcane borer, Diatraea saccharalis (Fabricius), bollworm, Heliothis zea (Boddie), and pink bollworm, Pectinophora gossypiella (Saunder), in the Soviet Union (Dysart, 1973; Beglyarov and Smetnik, 1977), China (Chen and Pang, 1974; Tseng, 1975; Huffaker, 1977) and Mexico (Jiminez, 1980). However, the use of Trichogramma presents many problems, one of which is short life span. If a crop is to be protected from a lepidopterous pest, most of the pest eggs must be destroyed over a prolonged period

of time, usually three weeks to a month and possibly much longer. Thus it is necessary to make repeated releases at three to five day intervals. Adverse weather conditions may also inhibit Trichogramma activity and may result in the escape of a host population (Parker and Pinnell, 1972).

Of the other kinds of natural enemies that might be considered for utilization in an augmentation program, parasitoids that attack the larval stage do not appear promising. First, most of the species that might be mass reared emerge from their hosts after they have completed larval development. Release of a mass reared parasitoid of this kind might suppress a pest population but only after it has inflicted maximum injury to the crop. A second factor limiting the potential of a parasitoid is the dispersal capabilities of the adult females. One effort to test this method involved the use of an aphid parasite for control of potato aphids, Macrosiphum euphorbiae (Thomas), in Maine, but did not significantly reduce the aphid population (Shands et al., 1975). The authors attributed this to dispersal of the released stock and insufficient knowledge of the parasitoids' adult behavior.

Somewhat more promising results were obtained by Parker and Pinnell (1972) with imported cabbage worm control in Missouri. These workers released laboratory reared imported cabbage

worm adults in the field beginning in early season in order to maintain a continuing high host egg population for Trichogramma evanescens (Westwood). However, because T. evanescens was inactive during periods of cold rainy weather, it was necessary to release the larval parasitoid Apanteles rubecula (Marshall) in order to eliminate the larvae resulting from eggs that escaped during periods when T. evanescens was not active.

The one great advantage of Trichogramma is the ease with which very large numbers can be produced at comparatively low cost (Metcalf et al., 1962; Morrison et al., 1976; Morrison and King, 1977).

Predators constitute a third category of natural enemies that might be manipulated sucessfully through augmentation. Several lines of evidence point to this possibility. First, there is much empirical evidence indicating that outbreaks of foliage feeding insects, such as the cotton bollworm and the velvetbean caterpillar, normally occur after an insecticide has been used to control an earlier pest in the same season, or in areas having a past history of heavy insecticide use (van den Bosch and Messenger, 1973).

Whitcomb (1973) and Neal (1974) have reported that approximately a thousand species of predacious arthropods occur in the soybean fields of the southeastern United States. While only a few of these are ever sufficiently

numerous to have a significant impact on an outbreak pest population, their joint action is probably the most important factor in maintaining non-outbreak pest populations at non-economic levels (Sailer, 1971). If this view of the importance of predators is accurate, it should be possible to reduce pest populations through the production and release of appropriate numbers of an effective predator.

Predators have one advantage over Trichogramma in that most are comparatively long lived. Many are predacious in both the immature and adult stages. Generally, they are well-adapted to survive periods of prey scarcity either by migration or by subsistence feeding on plants. They are less affected by weather extremes, and less likely to be rendered ineffective by periodic environmental unfavorability (DeBach, 1971). They have two major disadvantages. First, few will exhibit more than a functional response to an increase in prey numbers; thus, in an increasing prey population, the predator population does not increase rapidly except as recruits are added from the outside. As the prey increases and passes a point at which the predator population becomes satiated, it will inflict a progressively lower mortality rate. While the abundant food resource may result in an increase of the predator population in the next generation, this will be too late to influence crop damage.

Those predators that do exhibit a rapid numerical response are highly effective in reducing prey populations.

A good example is the predacious mite, Phytoseilus persimilis Allen, currently being used in north European countries for control of the two-spotted mite, Tetranychus urticae Koch, in greenhouses (Hussey and Bravenboer, 1971).

While none of the predators present in soybean fields are known to be of a kind that would respond numerically to increasing populations of the velvetbean caterpillar, numerous predacious species that prey on eggs and larvae are available as possible candidates for augmentation. One of the commonly encountered predators is the spined soldier bug, Podisus maculiventris (Say). This North American stinkbug has been the subject of numerous studies and is readily reared in the laboratory on greater wax moth larvae, Galleria mellonella (L.). The ease with which wax moth larvae can be produced at relatively low cost suggested the possibility that the velvetbean caterpillar could be controlled through the release of P. maculiventris. The fact that nymphs released as 2nd or 3rd instars could not leave the field until sometime after becoming adults would result in the continued presence of the predator population over a period of at least three weeks and hopefully provide protection during the critical time of pod set. If released early in the developing velvetbean caterpillar infestation, the small nymphs would initially feed on early instars of the caterpillar, thereby destroying larger numbers than if released later when one mature caterpillar would feed on

several 2nd or 3rd instar bugs to repletion. As 4th and 5th instar, the bugs greatly increase consumption of prey. Thus, if released in sufficient numbers to simulate a numerical response to the prey population, and with persistence of the released stock during the critical period of crop growth, prospects for control of velvetbean caterpillat through augmentation of the predacious stinkbug population appeared to be feasible, at least on an experimental basis.

During the period when a field experiment to test the feasibility of controlling velvetbean caterpillar through augmentation releases of P. maculiventris was being considered, a second species of predacious stinkbug became available for study. This stinkbug was the southeast Asian species, Eocanthecona furcellata (Wolff). In recent years this species has been studied by Amporn Winotai* (personal communication) in Thailand, and Chu and Chu (1975 a, b) in Taiwan. Based on information contained in these publications and in correspondence with Dr. Banpot Napompeth (personal communication), National Biological Control Research Center, Bangkok, Thailand, it appeared that E. furcellata shared many characteristics with P. maculiventris. Both have a very wide range of prey with a preference for

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foliage feeding lepidopterous larvae. Both can be easily reared in the laboratory. Dr. Napompeth and others who have worked with E. furcellata regard the species as a valuable predator in field crop situations. From this knowledge, an obvious question followed: If used in an augmentation program for control of a pest such as the velvetbean caterpillar, which species would be more effective and which could be produced in the required numbers at the least cost?

Because of its geographic restriction to the tropical and subtropical countries of southeastern Asia, there is also reason to expect that E. furcellata might be better adapted to the climate of Florida and other Gulf Coast areas of the United States than P. maculiventris. With its range of distribution covering most of North America from southern Canada to northern Mexico, P. maculiventris is clearly adapted to live in a wide range of climatic conditions. However, with such a broad tolerance to environmental conditions, it would seem that P. maculiventris might fail to compete successfully with a species specifically adapted to subtropical and tropical conditions, assuming that both otherwise occupied the same ecological niche. Should this be the case, it is possible that if established in the southern United States, E. furcellata could competitively displace P. maculiventris from the southern portion of its present range. As a superior competitor, it could

be argued that such a displacement would result in a higher level of predator activity in those areas now occupied by P. maculiventris.

In considering the introduction and study of E. furcellata, a third consideration also was of concern. With the single exception of the southern green stinkbug, Nezara viridula (L.), species of the family Pentatomidae are notoriously poor colonizers. Repeated attempts to introduce the predacious pentatomid Perillus bioculatus (F) into France and other European countries from North America for control of the Colorado potato beetle, Leptinotarsa decemlineata (Say), have failed (Feytaud 1938). An effort to colonize P. maculiventris in Yugoslavia also failed (Tadic 1971). Therefore, the opportunity to study E. furcellata offered an occasion to gain more knowledge about the factors influencing success and failure of efforts to colonize beneficial insects in new and seemingly suitable environments.

With these considerations in mind, a stock of E. furcellata was obtained from Thailand through the generous assistance of Dr. Napompeth in the early spring of 1980, and soon after a stock of P. maculiventris was obtained from the field locally and a colony was established. The subsequent studies had three primary objectives: first, to compare rates of development, fecundity, and longevity of the two species under different conditions of temperature and light length; second, to develop an economical

method of rearing the number of nymphs of both species needed to carry out a comparative field efficacy test; third, to develop an economical method of rearing large numbers of the factitious host, G. mellonella, as food for both species.

While no special effort was made to colonize E. furcellata for the purpose of establishing a self-perpetuating population, the conditions of the field efficacy test constituted a very substantial field release, and it was hoped that successful colonization might result. Also, in the event of failure of the field test to establish a population, it was hoped that information from the comparative studies would provide some clues as to reasons for failure and increase the prospects for successfully colonizing E. furcellata through future releases.

CHAPTER TWO
COMPARATIVE DEVELOPMENT, FECUNDITY, AND LONGEVITY OF EOCANTHECONA FURCELLATA AND PODISUS MACULIVENTRIS UNDER DIFFERENT TEMPERATURE AND DAY LENGTH CONDITIONS

Introduction

Several North American authors have studied the life history of Podisus maculiventris. Few cover all aspects of development, sexual behavior, fecundity, or longevity. Still fewer provide information obtained under controlled conditions of temperature and light. Similarly, there is considerable published information concerning Eocanthecona furcellata. Much of this is of a kind similar to that published by the North American authors on P. maculiventris. No one has investigated the effects of temperature and photoperiod combinations on both species at the same time for comparison of their development, fecundity, and longevity.

The main objective of the research reported here was to compare the response of these two asopine species to different temperatures and photoperiods in order to determine which of the two species exhibits characteristics suggesting better adaptation to subtropical environments. It was also expected that information drawn from these studies would be useful in planning and carrying out a field experiment designed to compare the efficacy of the two asopine species

when mass reared and released for control of the velvetbean caterpillar, Anticarsia gemmatalis (Hubner).

Literature Review

Egg stage

Eggs of P. maculiventris hatch in 4-7 days (Mukerji and LeRoux, 1964), or 5 days (Richman and Whitcomb, 1978) at 27°C, or 6-8 days at 21°C (Warren and Wallis, 1971), or 5 days when placed in an insectary in Massachusetts under as close to natural conditions as possible (Forbush and Fernald, 1896).

The egg stage of E. furcellata lasted 7 days at 28°C (Chu and Chu, 1975a, b).

Duration of Nymphal Development

Mukerji and LeRoux (1964) found that P. maculiventris required from 25 to 31 days to complete development from egg hatch to adult emergence when reared at 27°C. Richman and Whitcomb (1978), who also reared the species at 27°C, reported completion of nymphal development in 21.7 days. When reared at 21°C by Warren and Wallis (1971), the duration of development was increased to 28.7 days, while Forbush and Fernald (1896) used an open insectary and reported adult emergence in 22 days. Although the American authors reared P. maculiventris at 27°C while the Asian author Chu (1975) reared E. furcellata at 28°C, it would appear that E. furcellata develops more rapidly than P. maculiventris since

he reported completion in 17 days. While not specifying a rearing temperature, Amporn Pipatwatanakul (1980) (personal communication) reported 18.88 ± 1.01 days as required for development of E. furcellata, supporting the view that development is more rapid in this species.

Adult

Fecundity. Richman and Whitcomb (1978) reported that P. maculiventris deposited 17-20 eggs in a loose mass, while Mukerji and LeRoux (1964) found that eggs were laid in masses of 22 to 71 and they determined maximum fecundity to be 1220 eggs with a mean production of 362.7 eggs per female.

According to Chu and Chu (1975a, b), E. furcellata females lay masses of a few to more than 100 eggs. Cherian and Brahmacheri (1941) were more precise and indicated eggs were laid in masses of 25-180. Amporn Pipatwatnakul (1981) (personal communication) noted average egg production to be 341 ± 128.9.

Factors influencing fecundity. Evans (1982) found body size to be strongly correlated with numbers of eggs produced by female P. maculiventris. Large females laid eggs sooner, more frequently, and in larger numbers per mass than smaller females.

Mating. Mukerji and LeRoux (1964) found that P. maculiventris mated 2 to 4 days after becoming adult, and according to Chu (1975) E. furcellata mated about 6 days after adult emergence.

Sex ratio. Mukerji and LeRoux (1964), under conditions of normal food supply, found the sex ratio of P. maculiventris to be 1:1 with a higher proportion of males occurring when food was scarce. Chu (1975) observed the same to be true for E. furcellata.

Preoviposition period. Mukerji and LeRoux (1964) reported a preoviposition period of 3 to 4 days for P. maculiventris. Chu (1975) found that E. furcellata required 10 days, while Amporn Pipatwatanakul (1981) (personal communication) reported 24.8 ± 2.1 days. There is no clear indication as to why these two authors should have found such a great difference in the preoviposition period of E. furcellata; however, in either case it seems significantly longer than that reported for P. maculiventris. Chu (1975) also found temperature correlated to the preoviposition period. He reported that preoviposition periods were 20.1, 14.0, 9.2, and 5.8 days at 20, 25, 30, and 35°C, respectively.

Longevity. Mukerji and LeRoux (1964) found the average longevity of female P. maculiventris to be 125.3 days and that of the male 179.8 days; while according to Chu (1975), female E. furcellata lived only about 20 days and male only about 13 days at 27°C. Temperature is correlated to the longevity as reported by Chu (1975). He found longevity of male E. furcellata to be 51.8, 35.3, 24.6, and 15.2 days and longevity of females to be 29.8, 18.2, 12.7, and 8.6 days at 20, 25, 30, and 35°C, respectively.

Influence of Temperature on Development

For E. furcellata, the threshold temperatures, i.e., developmental zero, for eggs, nymphal, and adult development was 16.3, 15.4, and 15.4°C, respectively, and the thermal constant for egg, nymphal, and adult stages were 71.5, 215.9, and 134.1 degree-days (Chu, 1975).

Chu (1975) reported that the average duration of the egg stage was 13.6, 8.2, 5.2, and 4.5 days, and that the percentage of eggs hatching were 58.5, 93.7, 89.0, and 56.0 at 20, 25, 30, and 35°C, respectively. This revealed that the higher the temperature, the shorter the incubation period, but the highest percentage of eggs hatching was at 25°C. Above 40°C or below 15°C eggs failed to hatch. The most suitable temperature range for egg hatch, development of nymphs, oviposition, and adult life span was 25-30°C. Under optimum temperature condition eggs hatched after 2.5 days, nymphal development was completed in 14.3 days and females lived 24.6 days, while the adult life of males was only 12.7 days.

Generations per Year

Judging from existing life history data, it would appear that P. maculiventris completes more generations per year in Florida than does E. furcellata in Taiwan. Richman and Whitcomb (1978) suggested that the former might produce as many as 9-10 generations in Florida, while Chu and Chu (1975a) found only 5-6 generations for E. furcellata in Taiwan.

Influence of Prey on Nymph Survival and Fecundity of Adults

Podisus maculiventris mature and produce viable eggs when fed on two species of lepidopterous larvae: cabbage looper, Trichoplusia ni (Hubner), and soybean looper, Pseudoplusia includens (Walker) (Richman and Whitcomb, 1978). Mukerji and LeRoux (1964) reared P. maculiventris successfully on a diet consisting entirely of wax moth larvae, G. mellonella. These authors found that for normal development, the 2nd instar required one wax moth larva, the 3rd instar required 1-2 larvae, the 4th instar required 2-3, and the 5th instar required 3-4, and an adult consumed about 35 wax moth larvae during its life. Chu (1975) reported that nymphal mortality and adult fecundity were greatly influenced by the kind of prey offered. Nymphal mortalities were 8.1, 8.5, 14.0, 46.0, and 100% when fed with Chilo simplex (Butler), Pieris rapae (L.), Ostrinia nubilalis (Hbn.), Spodoptera litura (F.), and G. mellonella, respectively. When fed larvae of C. simplex or Ostrinia nubilalis, females deposited an average of 200-250 eggs.

Marston et al. (1978) reported an influence of different larval behavior among corn earworm, Heliothis zea (Boddie), cabbage looper, velvetbean caterpillar, and green cloverworm, Plathypena scabra (F.). They noted no significant effect of prey behavior on the ability of the predator, Podisus maculiventris, to contact a larva with its proboscis, though the approack behavior and the time

required to make contact varied. However, once contact was made, behavior of prey larvae significantly affected the ability of the predator to subdue the larvae. They suggested that pest management programs involving releases of P. maculiventris should consider the species composition of a pest population as a critical variable.

Waddill and Shepard (1975) reported that P. maculiventris responded to rise in temperature with an increase in prey consumption. They also found that the amount of time required for P. maculiventris to molt to each succeeding stage was influenced by the quality of the diet, with the duration of the nymphal stages generally decreasing as the prey stage increased, even though ample prey was provided in all test containers (more than would be consumed).

However, Cherian and Brahmacheri (1941) reported that when fresh green twigs and caterpillars were offered in rearing jars at the same time, E. furcellata in all stages except the 1st instar (which does not feed as a predator) fed on the plant sap first and only later turned their attention to the caterpillars.

Chu and Chu (1975a) reported that fecundity was significantly influenced by the species of prey on which E. furcellata nymphs were reared and maintained as adults. They reported that the total number of eggs oviposited per female was 221.5, 245.0, 156.0, and 148.2 when fed with C. simplex Ostrinia nubilalis, Pieris rapae, and S. litura larvae.

In the case of Podisus maculiventris, Mukerji and LeRoux (1964) reported that crowding had a considerable effect on oviposition. They suggested that oviposition is to some extent density dependent. They also pointed out that the difference in numbers of eggs laid from generation to generation was mainly due to the difference in temperatures at which females were reared.

Methods and Materials

Experiment One

Thirty mating pairs of both species, E. furcellata and P. maculiventris, were randomly chosen from a reared pool of adults that had emerged on the same day. Each pair was placed in a petri dish, 16 cm diameter by 2 cm deep. A disc of paper toweling and a section of green bean were placed in the bottom of each petri dish. The paper toweling and green bean were changed twice weekly. Cabbage looper or wax moth larvae were used and prey were provided daily. Ten pairs of each species (replications) were placed in each of three environmental chambers. The temperatures were set at 18.3, 23.9, and 29.4°C and the photoperiods of all three were set at 16:8 L:D.

Data relating to fecundity, fertility, and longevity were recorded daily. Twelve nymphs from a single egg mass of each pair were randomly selected and placed into a petri dish, 9 cm diameter by 1.5 cm deep, which was furnished with a single layer of paper toweling and a section of green

bean. Prey consisted of cabbage looper or wax moth larvae. The date of hatch, duration of each instar, date of emergence, sex ratio, date of first oviposition, and percentage of mortality were recorded and feeding behavior was observed.

Experiment Two

The procedure was identical to that in Experiment One except that the photoperiod was changed to 8:16 L:D.

Results

Egg Incubation Period

Significantly more time was required for incubation of E. furcellata eggs than for those of P. maculiventris at each of the temperature studies (Table 2-1). Egg development proceeded more rapidly in both species with increasing temperature. Table 2-2 indicates the occurrence of a significant species (S) by temperature (T) interaction at P=0.05.

First Instar

Data on the duration of the 1st nymphal instar of E. furcellata and P. maculiventris are presented in Table 2-3. Only at 23.9°C did 1st instar development differ between the two species with P. maculiventris developing more slowly. E. furcellata development did not differ at 23.9°C and 29.4°C, but proceeded more slowly at 18.3°C. With P. maculiventris, however, development did not differ at 18.3°C and 23.9°C and proceeded more rapidly at 29.4°C (Table 2-3).

TABLE 2-1
Duncan's Multiple Range Test for Duration of Egg Incubation Periods of E. furcellata and P. maculiventris at 3 Different Temperatures and 2 Photoperiodic Regimens

	No. Days of Incubation					
	18.33°C		23.88°C		29.44°C	
	E.f.*	P.m.**	E.f.	P.m.	E.f.	P.m.
L:D 16:8	13.2	7.7	12.1	5.6	6.8	3.9
L:D 8:16	16.0	9.9	12.0	7.3	5.1	4.6
TOTAL	29.2	17.6	24.1	12.9	11.9	8.5
AVERAGE	14.6	8.8	12.1	6.4	5.9	4.2
	a	c	b	d	d	e

*E. furcellata
**P. maculiventris

Values followed by the same letters are not significantly different at .05 level.

TABLE 2-2
Analysis of Variance for the Duration of Incubation Period of the Species (S) E. furcellata and P. maculiventris at 3 Different Temperatures (T) and 2 Different Photoperiodic Regimens (PH)

Source	DF	Sum of Squares	F-value	PR>F
Model	11	907.2	36.0	0.0001
Error	76	174.2		
S	1	342.6	149.5	0.0001
T	2	567.7	123.8	0.0001
PH	1	16.4	7.2	0.0090
S*T	2	78.0	17.0	0.0001**
S*PH	1	5.8	2.5	0.1148
T*PH	2	25.0	5.4	0.0062*
S*T*PH	2	5.8	1.3	0.2853

P=0.05

TABLE 2-3
Duncan's Multiple Range Test for Duration of 1st Instar Nymphal Development of E. furcellata and P. maculiventris at three Different Temperatures and Two Photoperiodic Regimens

	No. Days to Complete 1st Instar					
	18.33°C		23.88°C		29.44°C	
	E.f.*	P.m.**	E.f.	P.m.	E.f.	P.m.
L:D 16:8	6.0	5.0	3.7	4.8	3.1	4.1
L:D 8:16	11.5	8.1	5.0	6.7	3.7	4.0
TOTAL	17.5	13.1	8.7	11.5	6.8	8.1
TOTAL/2	8.7 a	6.5 ab	4.3 c	5.7 b	3.4 c	4.0 c

*E. furcellata
**P. maculiventris

Values followed by the same letter are not significantly different at the .05 level.

Table 2-4 reveals a significant species (S) by temperatures (T) interaction (P=0.05).

Second Instar

Time required to complete the second instar of both species is shown in Table 2-5. Table 2-6 indicates that no meaningful interaction occurred in the 2nd nymphal instar. However, overall, P. maculiventris developed more rapidly than did E. furcellata (Table 2-5).

Third Instar

Table 2-7 indicates that under conditions of long light, the 3rd nymphal instar development was similar at the three temperatures. However, under short photoperiod, E. furcellata developed more slowly than P. maculiventris at 18.3°C and 23.9°C. Photoperiod had no effect on P. maculiventris development, but E. furcellata developed more slowly under short light conditions at 18.3°C and 23.9°C. Temperature significantly altered development of both species only under the short light photoperiod. Table 2-8 shows the species (S) by temperature (T) by photoperiod (PH) interaction to be significant at P=0.05.

Fourth Instar

Table 2-9 shows the number of days required to complete the 4th instar for both species. No meaningful interactions or main effect differences occurred in the 4th nymphal instar development (Table 2-10).

TABLE 2-4
Analysis of Variance for Duration of the 1st Instar Development of the Species (S) of E. furcellata and P. maculiventris at 3 Different Temperatures (T) and 2 Different Photoperiodic Regimens (PH)

Source	DF	Sum of Squares	F-value	PR>F
Model	11	265.4	9.1	0.0001
Error	73	193.5		
S	1	0.04	0.02	0.9023
T	2	175.9	33.2	0.0001
PH	1	67.7	25.5	0.0001
S*T	2	32.5	6.1	0.0035*
S*PH	1	2.6	1.0	0.3228
T*PH	2	47.1	8.9	0.0004*
S*T*PH	2	4.99	0.9	0.3945

P=0.05

TABLE 2-5
Comparison of Time Required to Complete the 2nd Instar of E. furcellata and P. maculiventris at 3 Different Temperatures and 2 Photoperiodic Regimens

	No. Days to Complete the 2nd Instar					
	18.33°C		23.88°C		29.44°C	
	E.f.*	P.m.**	E.f.	P.m.	E.f.	P.m.
L:D 16:8	5.8	5.2	4.4	4.6	4.2	4.3
L:D 8:16	9.5	7.9	8.0	5.1	3.7	4.2
DIFFERENCE	3.7	2.7	3.6	0.5	0.5	0.1

*E.f.= Eocanthecona furcellata
**P.m.= Podisus maculiventris

TABLE 2-6
Analysis of Variance in number of Days of the 2nd Instar Development of the Species (S) E. furcellata and P. maculiventris at 3 Different Temperatures (T) and 2 Different Photoperiodic Regimens (PH)

Source	DF	Sum of Squares	F-value	PR>F
Model	11	159.4	8.1	0.0001
Error	72	129.0		
S	1	7.8	4.3	0.0407*
T	2	104.2	29.1	0.0001
PH	1	42.8	23.9	0.0001
S*T	2	9.8	2.7	0.0712
S*PH	1	6.0	3.4	0.0703
T*PH	2	39.2	11.0	0.0001**
S*T*PH	2	9.3	2.6	0.0822

P=0.05

TABLE 2-7
Comparison of Number of Days Required to Complete the 3rd Instar of E. furcellata and P. maculiventris at 3 Different Temperatures and 2 Different Photoperiodic Regimens

	No. Days to Complete 3rd Instar					
	18.33°C		23.88°C		29.44°C	
	E.f.*	P.m.**	E.f.	P.m.	E.f.	P.m.
L:D 16:8	4.8	5.1	4.5	4.6	4.1	3.9
	bcd	bc	cd	cd	cd	d
L:D 8:16	9.0	6.1	8.5	5.3	4.0	4.3
	a	b	a	bc	cd	cd
DIFFERENCE	4.2	1.0	4.0	0.7	0.1	0.4

*E. furcellata
**P. maculiventris

Values followed by the same letters are not significantly different at the .05 level.

TABLE 2-8
Analysis of Variance for Duration of the 3rd Instar Development of the Species (S), E. furcellata and P. maculiventris at 3 Different Temperatures (T) and 2 Different Photoperiodic Regimens (PH)

Source	DF	Sum of Squares	F-value	PR>F
Model	11	98.8	7.0	0.0001
Error	72	191.0		
S	1	13.3	10.4	0.0019
T	2	65.2	25.5	0.0001
PH	1	45.3	35.4	0.0001
S*T	2	9.6	3.8	0.0280
S*PH	1	15.6	12.2	0.0008
T*PH	2	23.2	9.1	0.0003
S*T*PH	2	15.7	6.2	0.0034*

P=0.05

TABLE 2-9
Comparison of Number of Days Required to Complete the 4th Instar of E. furcellata and P. maculiventris at 3 Different Temperatures and 2 Different Photoperiodic Regimens

	No. Days to Complete 4th Instar					
	18.33°C		23.88°C		29.44°C	
	E.f.*	P.m.**	E.f.	P.m.	E.f.	P.m.
L:D 16:8	4.6	5.0	4.5	4.3	4.1	4.1
L:D 8:16	7.0	6.3	6.5	5.3	3.6	3.1
DIFFERENCE	2.4	1.3	2.0	1.0	0.5	1.0

TABLE 2-10
Analysis of Variance for the Duration of the 4th Instar Development of the Species (S) E. furcellata and P. maculiventris at 3 Different Temperatures (T) and 2 Different Photoperiodic Regimens (PH)

Source	DF	Sum of Square	F value	PR>F
Model	11	78.2	5.3	0.0001
Error	72	96.5		
S	1	2.3	1.7	0.1966 NS
T	2	52.7	19.6	0.0001
PH	1	11.6	8.7	0.0044
S*T	2	0.9	0.3	0.7167
S*PH	1	2.9	2.1	0.1481
T*PH	2	25.9	9.7	0.0002*
S*T*PH	2	0.4	0.2	0.8563

P=0.05

Fifth Instar

Time required to complete the 5th instar for both species is shown in Table 2-11. Overall, E. furcellata developed more slowly than did P. maculiventris. Table 2-12 reveals that no meaningful interactions occurred in 5th nymphal instar development.

Total Nymphal Development

Under conditions of long light, E. furcellata and P. maculiventris nymphal development is similar at the three temperatures (Table 2-13). However, under the short photoperiod E. furcellata developed more slowly than P. maculiventris at 18.3°C and 23.9°C. Both species developed more slowly under short light at 18.3°C and 23.9°C, but at 29.4°C photoperiod length had no effect on development of either species. Table 2-14 shows the species (S) by temperature (T) by photoperiod (PH) interaction to be significant at P=0.05. Temperature significantly altered the rate of development of both species under both photoperiod regimens.

Nymphal Survival

Survival of the two species was similar at the extreme temperatures, but E. furcellata surpassed P. maculiventris at 23.9°C. Survival of E. furcellata was significantly reduced below 23.9°C, and P. maculiventris below 29.4°C (Table 2-15). Table 2-16 indicates that a significant

TABLE 2-11
Comparison of the Number of Days Required to Complete the 5th Instar of E. furcellata and P. maculiventris at 3 Different Temperatures and 2 Different Photoperiodic Regimens

	No. Days to Complete 5th Instar					
	18.33°C		23.88°C		29.44°C	
	E.f.*	P.m.**	E.f.	P.m.	E.f.	P.m.
L:D 16:8	11.0	8.9	10.4	7.9	7.7	5.6
L:D 8:16	14.5	12.4	11.0	6.0	5.6	4.9
DIFFERENCE	3.5	3.5	0.6	1.9	2.1	0.7

*E. furcellata
**P. maculiventris

TABLE 2-12
Analysis of Variance for the Duration of the 5th Instar Development of the Species (S) E. furcellata and P. maculiventris at 3 Different Temperatures (T) and 2 Different Photoperiodic Regimens (PH)

Source	DF	Mean	F-value	PR>F
Model	11	567.0	13.5	0.0001
Error	72	275.0		
S	1	91.5	24.0	0.0001**
T	2	391.2	51.2	0.0001
PH	1	3.7	1.0	0.3256
S*T	2	16.6	2.1	0.1207
S*PH	1	0.6	0.2	0.7038
T*PH	2	70.8	9.3	0.0003*
S*T*PH	2	11.1	1.5	0.2402

P=0.05

TABLE 2-13
Comparison of the Number of Days Required to Complete Total Nymphal Development of E. furcellata and P. maculiventris at 3 Different Temperatures and 2 Different Photoperiodic Regimens

	No. of Days					
	18.33°C		23.88°C		29.44°C	
Photoperiod	E.f.*	P.m.**	E.f.	P.m.	E.f.	P.m.
L:D 16:8	32.2 c	29.3 cd	27.5 d	26.2 de	23.2 ef	22.0 f
L:D 8:16	51.5 a	40.8 b	39.0 b	28.4 cd	20.6 f	20.5 f
DIFFERENCE	19.3	11.5	11.5	2.2	2.6	1.5

*E. furcellata
**P. maculiventris

Values followed by the same letters are not significantly different at the .05 level by Duncan's multiple range test.

TABLE 2-14
Analysis of Variance for the Duration of Nymphal Development of the Species (S) E. furcellata and P. maculiventris at 3 Different Temperatures (T) and 2 Different Photoperiodic Regimens (PH)

Source	DF	Sum of Squares	F-value	PR>F
Model	11	4216.0	35.9	0.0001
Error	72	768.4		
S	1	315.7	29.6	0.0001
T	2	3361.6	157.5	0.0001
PH	1	716.3	67.1	0.0001
S*T	2	147.1	6.9	0.0018
S*PH	1	108.3	10.2	0.0021
T*PH	2	903.5	42.3	0.0001
S*T*PH	2	103.3	4.8	0.0107*

P=0.05

TABLE 2-15
Duncan's Multiple Range Test for the Survival Rate of Nymphs of the Species E. furcellata and P. maculiventris at 3 Different Temperatures and 2 Different Photoperiodic Regimens

Photoperiod	18.33°C		23.88°C		29.44°C	
	E.f.*	P.m.**	E.f.	P.m.	E.f.	P.m.
L:D 16:8	48.3	40.8	59.5	44.4	57.5	59.1
L:D 8:16	20.8	42.5	54.1	30.8	61.6	64.1
TOTAL	69.1	83.3	113.6	75.2	119.1	123.3
AVERAGE	34.6 b	41.7 b	56.9 a	37.6 b	59.6 a	61.7 a

*E. furcellata
**P. maculiventris

Values followed by the same letters are not significantly different at 0.05 level.

TABLE 2-16
Analysis of Variance for the Mean Number of Nymphs to Complete Development of the Species (S) E. furcellata and P. maculiventris at 3 Different Temperatures (T) and 2 Different Photoperiod Regimens (PH)

Source	DF	Sum of Squares	F-value	PR>F
Model	11	148.1	3.3	0.0011
Error	68	274.8		
S	1	2.6	0.6	0.4256
T	2	86.9	10.8	0.0001
PH	1	7.4	1.8	0.1800NS
S*T	2	26.3	3.3	0.0446*
S*PH	1	2.9	0.7	0.3974
T*PH	2	14.4	1.8	0.1765
S*T*PH	2	12.4	1.5	0.2234

P=0.05

species by temperature interaction occurred in nymphal survival to completion of development.

Sex Ratio

The mean proportional numbers of males of E. furcellata and P. maculiventris were not significantly different in all situations except at 18.3°C under long light conditions, where significantly more males occurred in E. furcellata (Table 2-17). Table 2-18 indicates that a significant species by temperature by photoperiod interaction occurred with respect to sex ratio of male individuals completing nymphal development. Table 2-19 indicates that the mean proportional numbers of females of E. furcellata and P. maculiventris were not significantly different in all situations except at 23.9°C. Table 2-20 indicates that a significant species by temperature interaction occurred with respect to female individuals completing nymphal development. Under long light conditions more P. maculiventris females occurred at 18.3°C than 29.4°C (Table 2-21).

Preoviposition Period

Under conditions of long light, oviposition was begun earlier by P. maculiventris than by E. furcellata at 18.3°C and 29.4°C (Table 2-22). Preoviposition periods for the two species were similar at 23.9°C. With a reduced photoperiod, this effect occurred at 18.3°C and 23.9°C, with preoviposition periods similar at 29.4°C. Decreasing photoperiods

TABLE 2-17
Duncan's Multiple Range Test for the Mean Proportional Numbers of Male E. furcellata and P. maculiventris reared to Adult Stage at 3 Different Temperatures and 2 Different Photoperiodic Regimens

	Photoperiod			
	L:D = 16:8		L:D = 8.16	
Temperature (^{0}C)	E. f.*	P.m.**	E.f.	P.m.
18.33	4.0 a	2.3 bc	1.5 c	2.9 abc
23.88	3.6 ab	3.1 abc	3.5 abc	2.0 c
29.44	3.7 a	4.1 a	3.7 a	3.9 a

*E. furcellata
**P. maculiventris

Values followed by the same letters are not significantly different at P=0.05.

TABLE 2-18
Analysis of Variance for the Mean Proportional Numbers of Males of the Species (S) E. furcellata and P. maculiventris Reared to Adult Stage at 3 Different Temperatures (T) under 2 Different Photoperiodic Regimens (PH)

Source	DF	Sum of Squares	F-value	PR>F
Model	11	41.8	2.7	0.0001
Error	68	95.6		
S	1	1.1	0.8	0.03862
T	2	17.3	6.2	0.0035
S*T	2	4.8	1.7	0.1921
PH	1	4.8	3.4	0.891
S*PH	1	1.2	0.9	0.3573
T*PH	2	2.2	0.8	0.4554
S*T*PH	2	10.7	3.8	0.0268*

P=0.05

TABLE 2-19
Duncan's Multiple Range Test for the Mean Proportional Numbers of Female E. furcellata and P. maculiventris Reared to Adult Stage at 3 Different Temperatures

Temperature (°C)	Species	
	E. furcellata	P. maculiventris
18.33	1.6 b	2.4 b
23.88	3.4 a	1.9 b
29.44	3.4 a	3.4 a

Value followed by the same letters are not significantly different at P=0.05.

TABLE 2-20
Analysis of Variance for the Mean Proportional Numbers of Females of the Species (S) E. furcellata and P. maculiventris Reared to the Adult Stage at 3 Different Temperatures (T) and 2 Different Photoperiodic Regimens (PH)

Source	DF	Sum of Square	F-value	PR>F
Model	11	46.9	4.1	0.0001
Error	68	71.1		
S	1	0.3	0.3	0.5744
T	2	26.9	12.9	0.0001
PH	1	0.3	0.3	0.6039 NS
S*T	2	12.2	5.8	0.0046*
S*PH	1	0.4	0.4	0.5507
T*PH	2	5.5	2.6	0.0784
S*T*PH	2	0.1	0.1	0.9708

P=0.05

TABLE 2-21
Sex Ratio of E. furcellata and P. maculiventris
Reared to the Adult Stage at Three Different
Temperatures and Two Different Photoperiodic Regimens

°C Temperature	L:D 16:8						L:D 8:16					
	E. furcellata			P. maculiventris			E. furcellata			P. maculiventris		
	No. of		Ratio	No. of		Ratio	No. of		Ratio	No. of		Ratio
	F*	M**	F:M	F	M	F:M	F	M	F:M	F	M	F:M
18.33	1.8	4.0	1:2.2	2.6	2.3	1:0.9	1.0	1.5	1:1.5	2.3	2.9	1:1.3
23.88	3.6	3.6	1:1	2.1	3.1	1:1.5	3.0	3.5	1:1.2	1.7	2.0	1:1.2
29.44	3.2	3.7	1:1.2	3.0	4.1	1:1.4	3.7	3.7	1:1	3.8	3.9	1:1

*F=Female
**M=Male

TABLE 2-22
Comparison of the Duration of the Preoviposition Period
of E. furcellata and P. maculiventris Females

	No. of Days of Preoviposition								
	18.33°C			23.88°C			29.44°C		
Photoperiod	E.f.*	P.m.**	Diff***	E.f.*	P.m.**	Diff***	E.f.*	P.m.**	Diff***
L:D = 16:8	14.8 b	10.5 c	4.3	10.7 c	10.0 cd	0.7	9.0 cd	5.8 e	3.2
L:D = 8:16	18.0 a	13.7 b	4.3	14.8 b	9.0 cd	5.8	9.2 cd	8.1 d	1.1
DIFFERENCE	3.2	3.2		4.1	1.0		0.2	2.3	

*E.f.=E. furcellata
**P.m.=P. maculiventris
***Diff=Difference

Values followed by the same letters are not significantly different at P=0.05.

significantly lengthened preoviposition in both species at 18.3°C, while at 23.9°C this occurred only in E. furcellata, and at 29.4°C only in P. maculiventris. Under long light oviposition was delayed below 23.9°C in E. furcellata and below 29.4°C in P. maculiventris. With reduced photoperiod E. furcellata was subjected to additional delay with each incremental reduction in temperature, while in P. maculiventris, significant delay occurred only below 23.9°C. Table 2-23 indicates that a significant species (S) by temperature (T) by photoperiod (PH) interaction occurred with respect to the length of the preoviposition period.

Number of Egg Masses

Table 2-24 indicates that under long light the number of egg masses each species laid when held at 29.4°C and 23.9°C was similar, but P. maculiventris laid 4.5 times as many egg masses as E. furcellata at 18.3°C. With reduced light, both species again laid similar numbers of egg masses at the two higher temperatures, but there was a 4.4-fold difference at 18.3°C. Photoperiod had a significant effect on egg mass production only at 18.3°C; light reduction produced a 6-fold decrease in both species. Temperature had no significant effect on E. furcellata egg mass numbers under long light, but under reduced photoperiods, significantly more were produced at 29.4°C. Conversely, temperature had no significant effect on P. maculiventris under

TABLE 2-23
Analysis of Variance for Preoviposition Periods of the Species (S) E. furcellata and P. maculiventris at 3 Different Temperatures (T) and 2 Different Photoperiodic Regimens (PH)

Source	DF	Sum of Squares	F value	PR>F
Model	11	889.8	15.7	0.0001
Error	91	469.1		
S	1	242.8	47.1	0.0001
T	2	586.9	56.9	0.0001
PH	1	89.9	17.4	0.0001
S*T	2	18.3	1.8	0.1755
S*PH	1	5.4	1.1	0.3077
T*PH	2	14.4	1.4	0.2529
S*T*PH	2	59.2	5.7	0.0045*

P=0.05

TABLE 2-24
Comparison of the Mean Number of Egg Masses Laid by E. furcellata and P. maculiventris Females at Three Different Temperatures and Two Different Photoperiodic Regimens

	No. of Egg Masses					
	18.33°C		23.80°C		29.44°C	
Photoperiod	E.f.*	P.m.**	E.f.	P.m.	E.f.	P.m.
L:D 16:8	5.2 bcde	23.9 a	3.2 de	8.6 bcd	7.3 bcd	6.9 bcd
L:D 8:16	0.9 e	4.0 cde	4.2 cde	6.9 bcd	10.9 b	9.7 bc
DIFFERENCE	4.3	19.9	1.0	1.7	3.6	2.8

*E. furcellata
**P. maculiventris

Values followed by the same letters are not significantly different at P=0.05.

short light conditions but under increased photoperiod egg mass production was significantly increased at 18.3°C. Table 2-25 indicates a significant species (S) by temperature (T) by photoperiod (PH) interaction at P=0.05.

Fecundity

Table 2-26 indicates that under conditions of long light, P. maculiventris produced more eggs than E. furcellata at 18.3°C, but egg production was similar for the two species at higher temperatures. With reduced light, the two species produced similar numbers of eggs at each of the temperatures studied. Photoperiod did not significantly alter egg production by E. furcellata, but reduced photoperiod produced a significant 7-fold decrease in P. maculiventris fecundity at 18.3°C. At the other temperatures, photoperiod had no effect. E. furcellata laid significantly more eggs at 29.4°C than at lower temperatures under both photoperiod regimens. P. maculiventris fecundity was significantly increased at 18.3°C under long light conditions, but with reduced light, temperature had no significant effect on egg production. Results show that P. maculiventris laid the most eggs at low temperature while the reverse was true of E. furcellata. Such behavior may reflect the geographic origins of the two species. Table 2-27 indicates a significant species (S) by temperature (T) by photoperiod (PH) interaction at P=0.05.

TABLE 2-25
Analysis of Variance for the Mean Number of Egg Masses Laid by the Species (S) E. furcellata and P. maculiventris Females at 3 Different Temperatures (T) and 2 Different Photoperiodic Regimens (PH)

Source	DF	Sum of Square	F value	PR>F
Model	11	3775.7	10.2	0.0001
Error	108	3643.9		
S	1	667.4	19.8	0.0001
T	2	221.2	3.3	0.0415
PH	1	285.2	8.5	0.0044
S*T	2	691.1	10.2	0.0001
S*PH	1	304.0	9.0	0.0033
T*PH	2	1282.5	19.0	0.0001
S*T*PH	2	324.2	4.8	0.0100*

P=0.05

TABLE 2-26
Comparison of the Mean Number of Total Eggs Laid per Female
E. furcellata and *P. maculiventris*
at Three Different Temperatures and
Two Different Photoperiodic Regimens

	Total Number of Eggs					
	18.33°C		23.88°C		29.44°C	
Photoperiod	E.f.*	P.m.**	E.f.	P.m.	E.f.	P.m.
L:D 16:8	262.3 bcdef	934.2 a	205.7 cdef	394.6 bcd	482.2 b	265.0 bcdef
L:D 8:16	23.9 f	131.5 def	110.4 ef	238.3 bcdef	438.7 bc	364.1 bcde
DIFFERENCE	238.4	802.7	95.3	156.3	43.5	99.1

Values followed by the same letters are not significantly different at 0.05 level.

*E. furcellata
**P. maculiventris

TABLE 2-27
Analysis of Variance for Mean Number of Total Eggs Laid by the Species (S) E. furcellata and P. maculiventris Females at Three Different Temperatures (T) and Two Different Photoperiodic Regimens (PH)

Source	DF	Sum of Squares	F Value	PR>F
Model	11	6184114.2	8.1	0.0001
Error	108	7494684.6		
S	1	539216.1	7.8	0.0063
T	2	468943.4	3.4	0.0377
PH	1	1275553.2	18.4	0.0001
S*T	2	1443218.5	10.4	0.0001
S*PH	1	194246.5	2.8	0.0972
T*PH	2	1600675.2	11.5	0.0001
S*T*PH	2	662261.3	4.8	0.0103*

P=0.05

Sterile Eggs

Table 2-28 indicates that both species laid similar numbers of infertile eggs at the two photoperiods. However, while E. furcellata laid comparable numbers of sterile eggs under the two photoperiod regimens, P. maculiventris laid 3-fold more under long than short photoperiods. Table 2-29 indicates a significant species by photoperiod interaction at P=0.05.

Fertile Eggs Which Failed to Hatch

As temperature increased, the numbers of fertile E. furcellata eggs which failed to hatch also increased, while those of P. maculiventris decreased (Table 2-28). Table 2-30 indicates that there was a significant species by temperature interaction at P=0.05.

Fertility

Table 2-28 indicates that the number of viable eggs which hatched differed for the two species only under 18.3°C, long light conditions, with P. maculiventris producing 17.5 times more than E. furcellata. Photoperiod significantly altered fertility only in P. maculiventris at 18.3°C; approximately 8 times as many eggs hatched under long light than under short light conditions. With the long photoperiod, increasing temperature increased egg hatch in E. furcellata, but decreased it in P. maculiventris. With reduced light, temperatures did not significantly alter the

TABLE 2-28
Mean Number of Sterile, Failed Hatch, and Hatched Eggs Laid by E. furcellata and P. maculiventris under Three Different Temperatures and Two Different Photoperiodic Regimens

	No. of Eggs					
	18.33°C		23.88°C		29.44°C	
Photoperiod	E.f.*	P.m.**	E.f.	P.m.	E.f.	P.m.
L:D 16:8						
Sterile	198.0	301.3	67.8	193.4	129.1	129.1
Fail Hatch	31.5	58.6	38.8	29.7	46.7	8.5
Hatched	32.8	574.3	99.1	171.5	306.4	127.0
TOTAL	262.3	934.2	205.7	394.6	482.2	265.0
L:D 8:16						
Sterile	19.1	49.9	97.7	90.3	254.5	57.6
Fail Hatch	3.3	12.0	3.0	26.8	16.3	17.6
Hatched	1.5	69.5	9.7	121.2	167.9	288.9
TOTAL	23.9	131.5	110.4	238.3	438.7	364.1

*E.f.=E. furcellata
**P.m.=P. maculiventris

TABLE 2-29
Analysis of Variance for the Mean Number of Sterile Eggs Laid by the Species (S) E. furcellata and P. maculiventris Females at Three Different Temperatures (T) and Two Different Photoperiodic Regimens (PH)

Source	DF	Sum of Squares	F Value	PR>F
Model	11	838670.9	2.4	0.0114
Error	108	3468078.4		
S	1	2594.7	0.1	0.7768
T	2	24127.4	0.4	0.6877
PH	1	168750.0	5.3	0.0238
S*T	2	173821.1	2.7	0.0713
S*PH	1	135206.5	4.2	0.0426*
T*PH	2	314696.5	4.9	0.0092*
S*T*PH	2	19474.8	0.3	0.7391

P=0.05

TABLE 2-30
Analysis of Variance for the Mean Number of Fertile Eggs Which Failed to Hatch Laid by the Species (S) E. furcellata and P. maculiventris at Three Different Temperatures (T) and Two Different Photoperiodic Regimens (PH)

Source	DF	Sum of Squares	F Value	PR>F
Model	11	33801.4	2.7	0.0047
Error	108	124405.4		
S	1	154.1	0.1	0.7152 NS
T	2	334.0	0.1	0.8652 NS
PH	1	15142.5	13.2	0.0004*
S*T	2	6994.2	3.0	0.0521
S*PH	1	2430.0	2.1	0.1493
T*PH	2	3723.5	1.6	0.2034
S*T*PH	2	5023.1	2.2	0.1180

P=0.05

number of E. furcellata nymphs hatching, but the hatch of P. maculiventris increased with increasing temperatures. Table 2-31 indicates a significant species (S) by temperature (T) by photoperiod (PH) interaction at P=0.05.

Longevity

Tables 2-32 and 2-34 indicate that longevity of males and females of E. furcellata and P. maculiventris was similar under conditions of long light, but males and females of P. maculiventris lived significantly longer and shorter, respectively, than corresponding individuals of E. furcellata under reduced light. Photoperiod had no effect on the longevity of either sex of E. furcellata, but photoperiod reduction significantly decreased and increased, respectively, the longevity of male and female P. maculiventris. Tables 2-33 and 2-35 indicate that significant species (S) by photoperiod (PH) interactions occurred for both males and females at P=0.05.

Discussion and Conclusion

A primary objective of the studies comprising this chapter was that of attempting to determine whether, through comparasion of the response of E. furcellata and P. maculiventris to different conditions of temperature and photoperiod,it would be possible to predict which species could be expected to have a competitive advantage under the prevailing climatic conditions of central and north Florida. Obviously there are many factors other than temperature and

TABLE 2-31
Analysis of Variance for the Mean Number of Hatched Eggs Laid by the Species (S) E. furcellata and P. maculiventris Females at Three Different Temperatures (T) and Two Different Photoperiodic Regimens (PH)

Source	DF	Sum of Squares	F Value	PR>F
Model	11	2880474.1	7.0	0.0001
Error	108	4038839.9		
S	1	450310.0	12.0	0.0007
T	2	300278.8	4.0	0.0208
PH	1	354579.4	9.5	0.0026
S*T	2	571794.8	7.6	0.0008
S*PH	1	14941.0	0.4	0.5287
T*PH	2	413819.7	5.5	0.0052
S*T*PH	2	774750.3	10.4	0.0001**

P=0.05

TABLE 2-32
Duration of Male Longevity of E. furcellata and P. maculiventris at Three Different Temperatures and Two Different Photoperiodic Regimens

Photoperiod	Longevity of Males (Days) 18.33°C	23.88°C	29.44°C	Average
L:D 16:8				
E. furcellata	88.3	84.7	30.1	67.7 b
P. maculiventris	84.1	79.1	21.9	61.7 b
L:D 8:16				
E. furcellata	84.9	56.0	57.2	66.0 b
P. maculiventris	127.0	17.3	15.1	53.1 a

Values followed by the same letters are not significantly different at 0.05 level.

TABLE 2-33
Analysis of Variance for the Mean Days of Male Longevity of the Species (S) E. furcellata and P. maculiventris at Three Different Temperatures (T) and Two Different Photoperiodic Regimens (PH)

Source	DF	Sum of Squares	F Value	PR>F
Model	11	119016.4	6.3	0.0001
Error	108	184830.8		
S	1	17088.5	10.0	0.0020
T	2	33782.1	9.9	0.0001
PH	1	23857.2	13.9	0.0003
S*T	2	406.1	0.2	0.8882
S*PH	1	26760.5	15.6	0.0001**
T*PH	2	16444.6	4.8	0.0100*
S*T*PH	2	677.3	0.2	0.8208

P=0.05.

TABLE 2-34
Duration of Female Longevity of E. furcellata and P. maculiventris at Three Different Temperatures and Two Different Photoperiodic Regimens

Photoperiod	Longevity of Females (Days) 18.33°C	23.88°C	29.44°C	Average
L:D 16:8				
E. furcellata	68.3	46.3	27.7	47.6 b
P. maculiventris	94.2	57.5	23.0	58.2 b
L:D 8:16				
E. furcellata	67.4	46.3	54.0	55.9 b
P. maculiventris	122.8	98.8	84.3	102.0 a

Values followed by the same letter are not significantly different at 0.05 level.

TABLE 2-35
Analysis of Variance for the Mean Days of Female Longevity of the Species (S) E. furcellata and P. maculiventris at Three Different Temperatures (T) and Two Different Photoperiodic Regimens (PH)

Source	DF	Sum of Squares	F Vaule	PR>F
Model	11	97321.0	10.2	0.0001
Error	108	93752.2		
S	1	24140.0	27.8	0.0001
T	2	34271.1	19.7	0.0001
PH	1	20332.0	23.4	0.0001
S*T	2	4039.8	2.3	0.1025
S*PH	1	9398.7	10.8	0.0014*
T*PH	2	4952.6	2.9	0.0620
S*T*PH	2	186.7	0.1	0.8982

P=0.05

photoperiod that could influence the competitive capabilities of the two species. One of these would be degree of immunity to mortality caused by parasitoids and predators. Another might be availability of preferred prey species or different ability to find and capture prey.

Relative susceptibility to natural enemies has been considered in chapter four and information concerning range of prey species utilized as food has been extracted from the literature and supplemented by laboratory observation. Based on available information there is little evidence that any of these factors affect the two species differently. However, because of their origin and distributional ranges there was reason to believe that they would respond differently to temperature and probably to photoperiod. It seems likely that they might also respond differently to humidity; however, there was no opportunity to test their response to this factor.

As a result of the experiments reported in this chapter in which E. furcellata and P. maculiventris were reared together in three different temperatures under two different photoperiods, there is clear evidence that these factors do influence the two species differently. Furthermore, these differences are of a magnitude that does permit certain predictions to be made regarding their reproductive potential under the climatic conditions of central and north

Florida. Such predictions are possible because of the interacting effects of temperature and photoperiod on fecundity, egg hatch, rate of development, nymphal survival, sex ratio, and preoviposition period.

Based on data for duration of development from egg to sexually mature adult (Tables 2-1, 2-13, and 2-22) the mean number of days to complete a generation of each species was established for three temperatures and two photoperiods. These data are summarized in Tables 2-36. With this data and data on eggs per female of each species (Table 2-28), the number hatched (Table 2-28), nymphal survival rate (Table 2-15) and sex ratio (Table 2-21) under corresponding conditions of temperatures and light, it is possible to calculate a potential rate of increase for each species during a generation.

As the experimental data on time required to complete a generation can be expressed in degree days under conditions of three temperatures and short (L:D 8:16) as well as long (L:D 16:8) photophases, it becomes possible to calculate the number of generations each species might be expected to produce in central and north Florida. All that is required is to obtain standard weather data, establish mean monthly temperatures and day lengths. Since Quincy, Florida, was the location of the field efficacy experiments involving E. furcellata and P. maculiventris, weather data from that station has been used to calculate the number of generatios and potential seasonal increase of the two species.

TABLE 2-36

Number of Days to Complete Generations of E. furcellata and P. maculiventris at 3 Different Temperatures and 2 Different Photoperiodic Regimens

Species	Stage	L:D 16:8			L:D 8:16		
		18.33°C	23.88°C	29.44°C	18.33°C	23.88°C	29.44°C
E.f.[a]	egg incubation	13.2	12.1	6.8	16.0	12.0	5.1
	nymph to adult	32.2	27.5	23.2	51.5	39.0	20.6
	preoviposition	14.8	10.7	9.0	18.0	14.8	9.2
	total	60.2	50.3	39.0	85.5	65.8	34.9
P.m.[b]	egg incubation	7.7	5.6	3.9	9.9	7.3	4.6
	nymph to adult	29.3	26.2	22.0	40.8	28.4	20.5
	preoviposition	10.5	10.0	5.8	13.7	9.0	8.1
	total	47.5	41.8	31.7	64.4	44.7	33.2

[a] E.f.=E. furcellata

[b] P.m.=P. maculiventris

In making these calculations it is appreciated that the resulting figures can be no more than rough approximations. There are several reasons why this is so. First, no lower temperature threshold was established for development of either species. As indicated by data in Tables 2-39 and 2-40, the lowest experimental temperature, 18.33°C, must be near the lower threshold for E. furcellata where under short light the rate of generation increase was 0.5 and only 3.02 for long light. Data for P. maculiventris on the same tables indicated corresponding rates of increase of 11.23 and 12.54 and thus a considerably lower threshold of development. Secondly, the actual mean monthly day length at Quincy, Florida, ranges from a minimum of 10 hours 16 min. in January to 14 hours 3 min. in July (Table 2-37) in contrast to the two experimental photoperiods that provided day lengths of 8 hours and 16 hours. Under conditions of the experiment E. furcellata was more sensitive to day length than P. maculiventris with all measured parameters more depressed under short light and more accelerated under long light. For purposes of calculating effect of light during the season at Quincy the mean day length during development of a generation was established. If longer than 12 hours, the long light development rate was used. If less than 12 hours, then the short light development rate was used.

With the above limitation in mind, it is assumed that no development would occur during the months of December,

TABLE 2-37
Temperature and Daylength for North Florida, 1981

Month	Temperature[a] (°C) Max.	Min.	Mean	Day Length[b] (hr) : (min)
Jan.	13.78	-0.83	6.50	10 : 16
Feb.	19.00	5.28	12.11	10 : 46
March	25.33	7.50	14.50	11 : 31
April	28.11	13.33	20.89	13 : 30
May	28.39	14.44	21.61	13 : 21
June	33.22	21.78	27.50	13 : 57
July	33.33	23.39	27.83	14 : 03
August	29.72	21.28	25.50	13 : 36
Sept.	30.56	17.67	24.11	12 : 45
Oct.	26.44	13.00	19.72	11 : 05
Nov.	22.39	8.11	15.22	11 : 00
Dec.	16.06	3.56	9.72	10 : 22

[a] Records from AREC, IFAS, Quincy station Florida.
[b] Compiled from U.S. Naval observatory data.

January and February. As indicated in Table 2-28, the mean monthly temperatures of these months are below any possible lower threshold for either species. In addition, prey required for egg production and nymphal development would be extremely scarce or nonexistent. In view of the uncertainty regarding thresholds of development, degree days for months March through November are based on zero as are those of development under the experimental temperatures.

In attempting to establish the number of generations each species might be expected to complete during the season, the number of degree days for each month was calculated on the basis of the number of degree days required for each species to complete development at the mean average temperature of the month. This was established by reference to the number of degree days required to complete a generation at the experiment temperature nearest the mean monthly temperature. When calculated as a mean for the period of a generation, day length for all generations exceeded 12 hours; therefore, all development was treated as occurring under long day. The results of these calculations are shown in Table 2-38. From this table it appears that P. maculiventris should complete 5 generations at Quincy, Florida, while E. furcellata would complete only four. In view of P. maculiventris' ability to develop more rapidly than that of E. furcellata at the lower temperature occurring in the spring and fall as indicated by Table 2-36, this difference in number of generations would be expected.

TABLE 2-38
Date Used for Calculating Potential Number Generation of
P. maculiventris (P.m.) and E. furcellata (E.f.) during 1 year

Month	Degree Days Required[a] P.m.	E.f.	Degree Days[b] Available	% of Development[c] P.m.	E.f.	Dates of Generation P.m.	E.f.
March	1180.5	1567.2	449.5	38.08	28.68	F_1: April 30	
April	998.2	1201.2	626.7	62.78	52.17		
May	998.2	1201.2	669.9	67.11	55.77		F_1: May 11
June	933.3	1148.2	825.0	80.40	71.85	F_2: June 11	F_2: June 27
July	933.3	1148.2	862.7	92.44	75.14	F_3: July 15	
August	998.2	1201.2	790.5	79.19	65.81	F_4: Aug. 20	F_3: Aug 8
Sept.	998.1	1201.2	723.3	72.47	60.21	F_5: Sept. 30	F_4: Sept 25
Oct.	1180.5	1567.2	611.3	51.78	39.01		
Nov.	1180.5	1567.2	456.6	38.68	29.13		

[a] Degree days required to complete a generation at the experimental temperature and photophase nearest the mean temperature and photophase of each month, e.g. March with mean temperature of 14.5°C and 11 hours 31 minutes day length is calculated as 18.33°C x 64.4 (days)=1180.5 degree days for P. maculiventris.

[b] Degree days available for development during each month adjusted for effect of mean temperature and photophase, e.g. March is 31 days, therefore, we have 14.5°C x 31 days= 449.5 degree days.

[c] $\frac{a}{b}$ x 100=a percentage of development in each month.

TABLE 2-39
Rate of Population Increase of E. furcellata and P. maculiventris
at 3 Different Temperatures and L:D 16:8

	L:D 16:8					
	18.33°C		23.88°C		29.44°C	
	E.f.[a]	P.m.[b]	E.f.	P.m.	E.f.	P.m.
% Hatched Eggs[c]	12.5	61.48	48.18	43.46	63.54	47.92
Nymphal Survival Rate	.483	.408	.595	.444	.575	.591
Number Nymphs Emerge to Adult	6	25	29	19	37	28
Sex Ratio Female:Male	(1:2.2) 2:4	(1:0.9) 13:12	(1:1) 14:14	(1:1.5) 8:11	(1:1.2) 17:20	(1:1.4) 12:16
Rate of Population Increase	3.02	12.54	14.33	9.65	18.27	14.16

[a] E.f.=E. furcellata
[b] P.m.=P. maculiventris
[c] % Hatched Eggs=(mean no. eggs hatched / mean total eggs laid by a female x 100)

TABLE 2-40
Rate of Population Increase of E. furcellata and P. maculiventris
at 3 Different Temperatures and L:D 8:16

	L:D 8:16					
	18.33°C		23.88°C		29.44°C	
	E.f.[a]	P.m.[b]	E.f.	P.m.	E.f.	P.m.
% Hatched Eggs[c]	6.25	52.85	8.79	50.86	38.27	79.35
Nymphal Survival Rate	.208	.425	.541	.308	.616	.641
Number Nymphs Emerge to Adult	1	22	8	16	24	51
Sex Ratio Female:Male	(1:1.5) 1:0 or 0:1	(1:1.3) 10:12	(1:1.2) 4:4	(1:1.2) 7:9	(1:1) 12:12	(1:1) 25:25
Rate of Population Increase	0	11.23	2.38	7.83	11.79	25.43

[a] E.f.=E. furcellata
[b] P.m.=P. maculiventris
[c] % Hatched Eggs=(mean no. eggs hatched / mean total eggs laid by a female x 100)

It might also be expected that the additional seasonal generation would enable P. maculiventris to overtake and surpass E. furcellata in population numbers present at the end of a season, given equal starting populations, despite the higher rate of increase for E. furcellata that is indicated for temperatures prevailing during the development of the 2nd and 3rd generations (Table 2-41). However, as shown by the progeny numbers in the same table, this advantage is not sufficient to overcome that of the additional P. maculiventris generation. With end populations of 85,692 P. maculiventris and 7738 E. furcellata, P. maculiventris might be expected to have a coefficient of competitive advantage of 11.04 under climatic conditions of Quincy, Florida.

This would of course assume that rates of increase would remain those indicated under experimental conditions. Many adverse physical and biotic factors not acting on the experimental population would greatly reduce the rate of increase and might affect the species differently. However, given this advantage of seasonal population increase and assuming that the two species do in fact occupy the same ecological niche, there seems little likelihood that E. furcellata could become established in north Florida and if established would be able to competitively displace P. maculiventris. The latter species advantage should diminish at more southern Florida localities and calculations for Homestead similar to those made for Quincy would probably show E. furcellata to have a decided advantage in that more tropical climate.

TABLE 2-41

Potential Progeny of 10 Pairs of Adults of Each Species of E. furcellata and P. maculiventris Through One Year

Generation	Species	Tem.[a]	Ph.[b]	Rate of Increase	Sex Ratio Female:Male	Progeny No. Total[c]	Progeny No. Female[d]
F_1	E. furcellata	L.	L.	3.02	1:2.2	30.2	9
	P. maculiventris	L.	L.	12.54	1:09	125.4	66
F_2	E. furcellata	M.	L.	14.33	1:1	129.0	65
	P. maculiventris	M.	L.	9.65	1:1.5	636.9	255
F_3	E. furcellata	H.	L.	18.27	1:1.2	1187.6	540
	P. maculiventris	H.	L.	14.16	1:1.4	3610.8	1505
F_4	E. furcellata	M.	L.	14.33	1:1	7738.0	3869
	P. maculiventris	H.	L.	14.16	1:1.4	21310.8	8880
F_5	E. furcellata	-	-	-	-	-	-
	P. maculiventris	M.	L.	9.65	1:1.5	85692	34277

[a]Tem.= Temperature : L=Low temperature (=18.3°C), M=mid temperature (=23.9°C), H.=high temperature (=29.4°C)

[b]Ph.= Photophase : L=long light (L:D 16:8)

[c]Total number =female number x rate of increase

[d]Female number = $\frac{\text{total number}}{\text{Sum of sex ratio}}$

CHAPTER THREE
FIELD EFFICACY TEST OF EOCANTHECONA FURCELLATA AND PODISUS MACULIVENTRIS IN SUPPRESSING FOLIAGE FEEDING PESTS IN SOYBEANS

Introduction

The United States, with a total crop of approximately 58 million acres, is the leading soybean producer in the world (USDA, 1978). Soybeans are the third leading crop in both acreage and value in the United States. In Florida soybean acreage has increased 25 fold since 1948, and a continuous and rapid expansion of soybean acreage has been predicted. Because of this extensive cultivation, existing pests of the crop are becoming more important and additional new insect pest problems are expected. As a result, soybean insect pest management is becoming increasingly important.

Among the insect pests, foliage feeding lepidopterous insects have caused some of the largest economic losses (Nickels, 1926; Sherman, 1920). Strayer (1973) reported velvetbean caterpillar, Anticarsia gemmatalis (Hubner), as the principal pest of soybean in Florida, causing annual losses of over $1.2 million. The problem has steadily worsened during recent years, and with the increasing cash value of soybeans there is a greater tendency for growers

to use chemicals for velvetbean caterpillar control. In the past four years chemical treatments, which have increased from zero to three applications per season, were usually required to control this pest (Collins, 1980; Herzog, personal communication). The danger of becoming locked into a chemical control cycle is a real one, considering the large number of potential pests that exist. Furthermore, the chemical insecticides can not actually solve insect problems, but can induce insect pest resurgence and secondary pest outbreaks (Pfrimmer, 1964; Falcon et al., 1968; Van Steenwyk et al., 1975). These conditions precipitated this research for a suitable non-chemical method for suppression of the velvetbean caterpillar.

Many reports have indicated that inundative releases of large numbers of predators show promise in the suppression of pest populations (Ridgway and Jones, 1968, 1969; van den Bosch et al., 1969; Collins, 1980).

Whitcomb (1973) reported that one thousand species of predators are present in the soybean ecosystem of Florida. Although predators are not synchronized with the necessary stage of the host as parasitoids are, they are usually effective at low prey densities (Sailer, 1971; Eveleens et al., 1973), and act most often as delayed density-dependent mortality factors (Hughes, 1963). Furthermore, most of the existing predators in Florida soybean fields affect eggs,

or 1st or 2nd larval instars of pests (Neal,1974; Collins, 1980). The native predators are either too small or not sufficiently numerous to stop the serious defoliation caused by large instar larvae. The asopine predators, with their large size, greater searching abilities and consumption potential , can inflict mortality on late stage velvetbean caterpillars and other pest larvae, and E. furcellata and P. maculiventris may meet such requirements.

Velvetbean caterpillar adult moths fly or are carried by the wind to the Florida panhandle and northward and their larvae populations build up to a peak level shortly after the moths have immigrated into the soybean fields (Strayer, 1973; Neal, 1974). During this time, native predator populations can not increase as quickly as the velvetbean caterpillar and no large numerical response can be expected from the native predators to aid in the reduction of the velvetbean caterpillar populations during the critical period of pod formation. Inundative releases of large numbers of predators, such as asopine bugs, is one method that could result in a rapid reduction of velvetbean caterpillar population to a noneconomic level .

P. maculiventris is an endemic asopine species with a wide range of prey. It is reported to prey on all stages of the Colorado potato beetle, Leptinotarsa decemlineata (Say) (Couturier, 1938), elm leaf beetle, Pyrrhalta luteola

(Muller), eastern tent caterpillar, Malacosoma americanum F., cotton bollworm, Heliothis zea (Boddie), cotton leafworm, Alabama argillacea Hubner, and cigar casebearer, Coleophora serratella (L.) (Morrill, 1906; Osborn, 1900; Whitmarsh, 1916; Hart, 1919; Baker, 1927; Landis, 1937; Esselbaugh, 1948; Coppel and Jones, 1962; Mukerji and LeRoux, 1964). P. maculiventris occasionally preys on velvetbean caterpillar (Watson, 1916; Waddill and Shepard, 1975b; Marston et al., 1978; Jones, 1979; Whitcomb, 1980; Herzog and Tood, 1980).

E. furcellata has been recognized as an important enemy of the imported cabbageworm, Pieris rapae (L.), armyworm, Spodoptera litura(L),and the hemp noctuid Anomia flava flava F. (Chu and Chu 1975a, b).

Techniques for mass production of asopine species have been published by several authors (Mukerji and LeRoux, 1964; Chu and Chu, 1975a,b). Using a factitious host, the greater wax moth, Galleria mellonella (L.), cultures of P. maculiventris and E. furcellata were established in our laboratory. Comparative studies on the development, fecundity, and longevity were made. These studies were made in preparation for an inundative release into a soybean field to compare the response of the two species velvetbean caterpillar, and their general field performance. The results of the field efficacy tests carried out in 1981 are reported here.

Literature Review

Insect Pests from Soybean Fields

Although soybean is attacked by a large number of insect pests, damage has been well documented for only a few of those species. The following species have been reported as the most prominent insect pests of soybeans: Velvetbean caterpillar, Anticarsia gemmatalis (Hubner), fall armyworm, Spodoptera frugiperda (Smith); beet armyworm, Spodoptera exigua (Hubner), corn earworm, Heliothis zea (Boddie), soybean looper, Pseudoplusia includens (Walker), cabbage looper, Trichoplusia ni (Hubner), stinkbugs, Acrosternum hilare (Say), Euschistus servus (Say), Euschistus tristigmus (Say), and Nezara viridula (L.), lesser cornstalk borer, Elasmopalpus lignosellus (Zeller), and three-cornered alfalfa hopper, Spissistilus festinus (Say) (Greene, 1975; Greene et al., 1976; Turnipseed and Kogan, 1976; Herzog and Todd, 1980 .

In Florida the velvetbean caterpillar is the most important defoliating pest of soybean (Neal, 1974; Greene, 1975; Strayer et al., 1977). Populations generally reach outbreak levels every year. A population outbreak of up to 200,000 per hectare often occurs in late August. Three or four generations occur each season in central and north Florida (Strayer, 1973; Menke and Greene, 1976), but only the latter two or three generations reach economic levels (Strayer, 1973). Herzog (1981) indicated that the

velvetbean caterpillar is the major target of insect management in soybeans in Florida.

The life history and behavior of velvetbean caterpillar have been reported by many authors (Watson, 1915, 1916; Douglas, 1930; Hinds, 1930; Hinds and Osterberger, 1931; Ellissor,1942).

Generally, an adult female lives an average of 12 to 14 days and lays approximately 400 eggs during this period. Eggs are usually laid singly or in small groups on the undersides of leaves, or on the upper surface of leaves (Greene et al., 1973). The eggs hatch in about three days. There are usually five or six larval instars. The larvae are very active and will drop from soybean plants and wiggle actively when disturbed. Larvae require about six days to develop through the first three stages (up to 1.27 cm long). The fourth, fifth, and sixth instar each takes about six days to develop and the entire life cycle requires 30-35 days (Watson, 1916; Reid, 1975).

Larvae less than 1.27 cm eat a total of one-third of an average leaflet every 48 hrs. However, larvae larger than 1.27 cm long eat approximately three and one-half average size soybean leaflets in 24 hrs. The third through the last larval instar consume about 98% of the individual's food intake (Reid, 1975).

Larval coloration is most commonly green although dark brown and black forms may be seen late in the season.

The head capsule is yellow and there are usually distinct yellow and white stripes running the length of the body. The sixth instar (about 5 cm long) moves down and pupates under the soil surface at the base of the soybean plants. Adult moths emerge in about ten days. Adult coloration is light brown with an oblique dark line across the front and back wings. Three or four generations can be produced annually. Velvetbean caterpillars overwinter in south Florida, the Caribbean Islands, and in Central and South America. Each summer the moths fly or are carried by wind to the Florida Panhandle and northward (Buschman et al., 1977b). In south and central Florida, adult moths appear in late June or July and the first larvae occur in mid to late July (Strayer, 1973; Neal, 1974). Buschman et al. (1977a) reported larvae in north Florida in early May and suggested that small numbers of pupae may survive some winters in north central Florida and may oviposit throughout the year.

Velvetbean caterpillar economic thresholds in Florida were reported by Strayer (1973). Chemical treatments are suggested when 1.27 cm larvae counts reach ten per 0.305 meters (i.e., 1 foot) of row prior to bloom, or four per 0.305 meters of row after bloom. These strong mobile pests have the capability of destroying soybean crops within one generation if natural enemies are lacking. The first peak

of velvetbean caterpillar occurs about late May or June (from soybean planting to mid-bloom). Because of the low population levels, no chemical treatment is usually needed at this time. The second peak occurs about mid-August to September, with populations often exceeding economic levels and the first treatment with insecticide usually takes place. The third peak occurs between the first and third weeks of September and treatment by insecticide is necessary for 90-95% of the acreage in north central Florida (Strayer, 1973). Insecticide treatment, from zero to three applications per season, were usually required to control velvetbean caterpillar in 1977, 1978, 1979, and 1980 (Herzog , personal communication)*. If insecticides have been used improperly to control this pest, an outbreak of the soybean looper, Pseudoplusia includens, occurs in soybean fields (Greene et al., 1974; Neal, 1974). Greene (1974) reported that heavy use of insecticides to control the second generation of velvetbean caterpillar directly induced soybean looper outbreaks. Shepard et al. (1977) also reported soybean looper outbreaks as well as pest resurgence resulting from depletion of natural enemies due to use of insecticides.

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Predacious Arthropods in Soybean Fields

Whitcomb (1973) reported that 1000 species of predators are present in the soybean ecosystem of Florida. Hasse (1971) and Neal (1974) reported 200-350 predacious species of arthropods collected from Florida soybean fields. The nabids and geocorines were two of the frequently collected groups from foliage samples. Neal (1974) reported Nabis spp., Geocoris spp., several carabids, and Labidura riparia (Pallas) as the most important predators in Florida soybean fields. Eight species of Nabidae have been reported (Hasse, 1971; Neal, 1974; Buschman et al., 1977a) including Reduviolus alternatus (Parshley), Reduviolus americoferus (Carayon), Reduviolus kalmii (Reuter), Nabicula sordidus (Reuter), Nabicula subcoleoptratus (Kirby), Tropiconabis capsiformis (German), Hoplistoscelis deceptivus (Harris), and Reduviolus roseipennis (Reuter). Of these, the most common species was R. roseipennis (Neal, 1974; Dietz et al., 1976). Shepard et al. (1974) found nabids to be the most abundant predator in soybean fields, with nymphs reaching levels of about five per row foot in mid to late September in South Carolina.

Adult female nabids deposit their eggs in the soft plant tissues in spring. Nabids pass through five nymphal instars before becoming adults in approximately 50 days. Pitre et al. (1978) pointed out that the peaking of nabids

occurs in June and July in Mississippi. Nabid nymphs peaked in late August and early September, at about 1.2 per row foot, in North Carolina (Dietz et al., 1976), 3 per row foot in South Carolina (Turnipseed, 1974), and 1 per row foot in Mississippi (Marston et al., 1976). Nabids overwinter in grassy ground cover and prefer shady habitats during the summer. Nymph and adult stages prey on aphids, leafhoppers, lygus bugs, spiders, and Lepidoptera eggs and larvae (Mundinger, 1922; Taylor, 1949; Werner and Butler, 1957; Dietz et al., 1976). Accounts of effectiveness of nabids as predators have been documented by Whitcomb and Bell (1964), Ridgway and Jones (1968), Turnipseed (1972), and Waddill and Shepard (1974).

Five Geocoris species were reported from row crops (Balduf, 1923; Blickenstaff and Huggans, 1962; Dunbar and Bacon, 1972; Elsey, 1972; Mead, 1972; Eveleens et al., 1973; Tugwell et al., 1973; Crocker, 1977; Wilkinson et al., 1979). These species are G. atricolor Montandon, G. bullatus (Say), G. pallens Stal, G. punctipes (Say), and G. uliginosis (Say). Of these, G. punctipes is the most common in soybean fields (Neal, 1974; Shepard et al., 1974).

Geocorines have large eyes on the sides of their heads which stick out beyond their bodies. Their coloration is most commonly silver with black markings. The size of an

adult is about 0.32 cm in length. Adult females oviposit eggs singly in terminal plant growth. There are five nymphal instars. Both adults and nymphs prey on the eggs and larvae of leafhoppers, psyllids, plant bugs, mites, thrips, and other arthropods (Whitcomb and Bell, 1964; Lingren et al., 1968; Tamaki and Weeks, 1972; Crocker et al. 1975; Lopez et al., 1976). During the summer, development from egg through five nymphal stages to adult takes approximately 30 days. The larger grayish-white nymphs and adults consume an average of 20 corn earworm eggs per day. The adults overwinter in low-growing grasses and ground trash. The accounts of their biology, feeding behavior, and feeding niches were reported by McGregor and McDonough (1917), van den Bosch and Hagen (1966), Champlain and Sholdt (1967), Tamaki (1972), Tamaki and Weeks (1972a), Sweet (1960), Stoner (1970), and Crocker (1977). Accounts of potential and effectiveness of Geocoris species as predators were documented by Lingren et al. (1968). Orphanides et al. (1971), Elsey (1972), Tamaki and Weeks (1927b), Turnipseed (1972), Barry et al. (1974), Neal (1974), Shepard et al. (1974), Waddill and Shepard (1974), and Deitz et al. (1976).

Pirate bugs, Orius spp., are common in soybean fields. The most common species is Orius insidiosus (Say). Their coloration is black with white markings on their wings,

and nymphs are pale orange. The length of the adult is about 0.16 cm. There are five nymphal instars. Adults and nymphs both prey on insect eggs, a variety of small worms, and other small soft-bodied insects. Development from egg to adult takes about 21 days.

At least 46 species from 13 different families of spiders are found in north and central Florida soybean fields (Neal, 1974; Deitz et al., 1976). The two species reported as the most abundant in the field are Oxyopes salticus Hentz and Chiracanthium inclusum (Hentz). Pitre et al. (1978) indicated that spiders such as O. salticus and Peucetia viridans (Hentz) peaked in June and July in Mississippi. LeSar and Unzicker (1978) reported O. salticus occurred on the average of 1 per 1.53 row meters in August and September in Illinois. Neal (1974), and Weems and Whitcomb (1977) indicated that O. salticus and P. viridans were the most abundant foliage dwelling spiders in Quincy, Florida. However, little is known about the role of these spider predators in the soybean ecosystem (Deitz et al., 1976). The accounts of biological information for spiders were documented by Whitcomb et al. (1963), Whitcomb and Bell (1964), Whitcomb and Eason (1967), Peck and Whitcomb (1970), Horner (1972), Wheeler (1973), Neal (1974), Turnipseed (1972), Burleigh et al. (1973), Deitz et al. (1976), Fuchs and Harding (1976), Johnson et al. (1976), Smith and Stedlbacher (1978), Whitcomb (1980), and many others.

Three species of Carabidae, Lebia analis DeJean, Calleida decora (F.), Calosoma sayi DeJean, were reported from soybean fields (Tugwell et al., 1973; Neal, 1974; Price and Shepard, 1978). Neal (1974) reported C. decora as the most common foliage dwelling carabid. The length of the carabid larvae is up to 3.85 cm. Carabids are most active at night.

Four coccinellids, Coleomegilla maculata (DeGeer), Hippodamia convergens Guerin-Meneville, Scymnus spp., and Stethorus spp., were reported from soybean fields (Tugwell et al., 1973; Neal, 1974; Deitz et al., 1976).

Four species of earwigs, Labidura riparis (Pallas), Doru lineare (Eschcholtz), Vostox brunneipennis (Serville), and Euborellia annulipes (lucas), were reported from Florida soybean fields (Hasse, 1971; Shepard et al., 1973; Neal, 1974; Walker and Newman, 1976; Price and Shepard, 1977; Travis, 1977; Buschman et al., 1977a; Price and Shepard, 1978). Earwigs are largely nocturnal with peak abundances occurring one hour after sunset (Ammar and Farrage, 1974; Walker and Newman, 1976; Buschman et al., 1977a). They prey on all life stages of lepidopterous and coleopterous insects, but rarely feed on plant materials (Bishara, 1934; Tawfik et al., 1972; Ammar and Farrag, 1974). Shepard et al. (1973), Price and Shepard (1978), and Waddill (1978) reported that the earwig responds functionally to increasing prey density.

Other information about predacious arthropods in soybeans can be found in Watson (1916), Dozier (1918), Balduf (1923), Nickels (1926), Douglas (1930), Hinds and Osterberger (1931), Ellisor (1942), Kretzschmar (1948), Blickenstaff and Huggans (1962), Neal et al. (1972), Buschman et al. (1977a), and Nickerson et al. (1977).

Asopine Predators

Economic importance

P. maculiventris frequently occurs on soybeans and comprises a noticeable part of the predator complex (Waddill and Shepard, 1975b), and was noticed as common in Florida soybean fields by Neal (1974).

Lopez et al. (1976) reported that P. maculiventris appears to have a unique potential for use in control efforts involving augmentation and conservation of naturally occurring predators. P. maculiventris has shown a considerable potential for reducing pests in soybeans and other crops (LeRoux and Mukerji, 1963; Waddill and Shepard, 1975b; Lopez et al., 1976; Whitcomb, 1980).

Other information on the impact of predators and possibilities for their utilization for suppression of pest populations has been cited by Fletcher and Thomas (1943), Ewing and Ivy (1943), Wille (1951), Bell and Whitcomb (1964), Whitcomb (1967), Lingren et al. (1968), Ridgway and Jones (1968, 1969), van den Bosch et al. (1969), Mukerji and

LeRoux (1969), Iwao and Wellington (1970), Waddill and Shepard (1975a), Lopez et al. (1976), Ignoffo et al. (1976), and Collins (1980).

Prey response to asopine predators

Behavioral interaction between the asopine predators and their prey has been reported by many authors (Sullivan and Green, 1950; Marston et al., 1976; Mukerji and LeRoux, 1969; Marston et al., 1978). Generally, after the asopine contacts a prey it attempts to insert its stylets through the integument. The prey usually reacts by vigorous movements of the head and thorax, or attempts to escape by crawling away. However, once penetration has been accomplished, the stylets are held within the integument by barbed tips and tend to coil within the hemocoele (Baker, 1927).

Different prey species have different behavior which greatly affect the ability of asopines to kill them. Velvetbean caterpillar larvae, for example, seem most sensitive to the stylets of the asopines and often escape before the predator penetrates their integument, or are frequently able to break the asopine predator's hold. Marston et al. (1978) reported that velvetbean caterpillars swing their bodies back and forth in a rapid, paroxysmal, whipping motion that usually causes them to drop from the plant, with or without the asopine attached. They concluded that differences in larval behavior among the prey species

had no significant effect on the ability of the predator to contact a larva with its proboscis though the approach behavior and the time required to make contact varied, but once contact was made behavior of the prey larvae significantly affected the ability of the predator to subdue them. They also point out that the velvetbean caterpillar reacted most vigorously to attack and suffered the least mortality (ca. 20-35%) when compared with other lepidopterous larvae in soybean fields. This finding suggested that species of prey vary in their response to the predator's attack and this may influence the asopine ability to successfully overcome its prey.

Iwao and Wellington (1970) reported that prey activity could influence a predator's response and thus affect the proportions of the surviving types of prey. The asopine may secrete a toxic or paralysis-causing substance, which, when injected into the prey, causes it to become immobile during feeding. This behavior could be of major importance in the successful predation of large victims (Baker, 1927).

Prey capture

Prey recognition is indicated by a sudden diversion of direction or cessation of movement followed by extension of the proboscis. Subsequent activity was positively correlated to prey movement (Iwao and Wellington, 1970). Marston et al. (1978) pointed out that the asopines rapidly approached and made contact with more active larvae, usually in less

than 1 minute. Less active larvae were approached deliberately; frequently five minutes or more elapsed before contact was made. They concluded that velvetbean caterpillar larval movement stimulated rapid attack by the asopines. Mukerji and LeRoux (1964) reported that short range olfactory cues were another possible means by which asopine bugs recognize their prey.

Prey preference

Asopine predators may not be effective in reduction of the egg stage of the pest population. Lopez et al. (1976) found that after release of P. maculiventris no substantial effect on the egg stage of pest populations was reported. However, the asopines consumed more large size pest larvae than the other predacious species present in the field.

Lopez et al.(1976) studied the comparative efficacy of predators on bollworms and tobacco budworms. They found that the 3rd instar to adult P. maculiventris were more efficient predators of the 3rd instar larvae of Heliothis spp. than Chrysopa carnea Stephens, G. punctipes, and Coleomegilla maculata (DeGeer). They concluded that the reduction effected by P. maculiventris was more evident in the larger larvae of Heliothis spp.

Collins (1980) studied different prey species attacked by P. maculiventris and found that P. maculiventris had a significant (P=0.05) preference for velvetbean caterpillar

and consumed 55% more velvetbean caterpillars than other lepidopterous prey species tested. He concluded that the preference of P. maculiventris for velvetbean caterpillar over other tested prey might be due to the species being present in conspicuously greater numbers. Thus, the results were probably due to conditions of the experiment rather than to preference.

Release number

Lopez et al. (1976) reported that release of P. maculiventris at rates of 246,914 per hectare (i.e. 100,000 per acre) in field cages resulted in substantial reductions in the number of Heliothis virescens (F.). They also reported that the effect of the release appeared as the reduction in larvae number after the seventh day and continued until the fourteenth day after the release.

Nymph dispersal

Waddill and Shepard (1975) reported that nymphs of P. maculiventris in soybeans tended to disperse along rows rather than across rows. They also reported nymphs as unable to move between adjacent rows in the absence of canopy overlap, and their number of recaptures was as low as 9.9% (700 released, 69 recaptured) or 11.6% (1200 released, 139 recaptured).

Lopèz et al. (1976) reported that about 1/3 of the released P. maculiventris were found alive in the field.

However, 20 days after release, survival rates were as low as 1.2% (246,914 per hectare released vs. 1200 recaptured). The survival rate, according to Waddill and Shepard (1975), was as low as 10.6% (202 recaptured vs. 1900 released).

Prey consumption

Lopez et al. (1976) reported that the 3rd instars of P. maculiventris eat about 117 eggs, or seventy-one 1st instar larvae, or three 3rd instar larvae, and the adults eat about 116 eggs, or thirty-five 1st instars, or six 3rd instars of Heliothis virescens. Similar research on the tent caterpillar, Malacosoma californicum pluviale (Dyar), has been reported by Iwao and Wellington (1970). They found the rate of larval consumption by P. maculiventris to be about one 4th instar larvae, or one-half of one 5th instar larvae, and concluded that the proportion of the types of larvae attacked did not vary appreciably with the predator's age or sex but did vary significantly in relation to the prey's instar.

Waddill and Shepard (1975a) studied predation by P. maculiventris on Mexican bean beetle, Epilachna varivestis (Mulsant) and found the number of prey consumed increased as temperature increased. They also found that prey consumption by P. maculiventris increased at a negatively accelerating rate as prey density increased.

Materials and Methods

A field test to compare the efficacy of E. furcellata and P. maculiventris for controlling the major target pest, velvetbean caterpillar, A. gemmatalis, was carried out between June and October 1981 in a soybean field belonging to the Agricultural Research and Education Center, IFAS, Quincy, Florida. Soybean was planted on June 1. Asopine nymphs were released on September 11, and September 22 at early pod formation stage of varities of "Centennial ."

A total of 64 plots was used. Each plot consisted of two 2.44 meter (i.e., eight-foot) rows of soybeans. Plots were isolated by removing one row of plants on either side of each plot and by removing plants from 1.22 meters of row on either end of each plot.

The number of nymphs released per plot, their ages, and the dates of release are shown in Table 3-1, 2, 3, and 4. The first release was made on September 11, 1981 (TT_1), and the second was made on September 22, 1981 (TT_2). The released nymphs were obtained from laboratory colonies reared on wax moth larvae. Nymphs were carefully counted and placed in 1.2 cm deep, 9 cm diameter petri dishes prior to release. The number of nymphs, their ages, and the number of release plots were marked on each petri dish, which were then arranged in the sequence in which they were to be released into the plots and placed in a carton to be carried to the field. All nymphs were fed with wax moth larvae before being placed in the cartons.

TABLE 3-1
Whole Number of Nymphs Released on September 11, 1981 (TT_1)

Plot No.	Species	Instar	Number Released (R_1) Per Foot in Row	Per Plot
1	E.f.[a]	2	8	128
2	E.f.	3	4	64
3	E.f.	4	2	32
4	E.f.	mixed		
		2	4	64
		3	2	32
		4	1	16
5	P.m.[b]	2	8	128
6	P.m.	3	4	64
7	P.m.	4	2	32
8	P.m.	mixed		
		2	4	64
		3	2	32
		4	1	16
9	E.f. + P.m.[c]			
	E.f.	2	4	64
	P.m.	2	4	64
10	E.f. + P.m.			
	E.f.	3	2	32
	P.m.	3	2	32
11	E.f. + P.m.			
	E.f.	4	1	16
	P.m.	4	1	16
12	E.f. + P.m.	mixed		
	E.f.	2	2	32
		3	1	16
		4	0.5	8
	P.m.	2	2	32
		3	1	16
		4	0.5	8
13	Unsampled check[d]			
14	Unsampled check			
15	Sampled check[e]			
16	Sampled check			

[a] E.f.=Eocanthecona furcellata

[b] P.m.=Podisus maculiventris

[c] E.f. + P.m.=E. furcellata and P. maculiventris

[d] Pest populations not disturbed

[e] Pest populations disturbed when sampled

TABLE 3-2
Half Number of Nymphs Released on September 11, 1981 (TT_1)

Plot No.	Species	Instar	Number Released ($R_{\frac{1}{2}}$) Per Foot in Row	Per Plot
33	E.f.[a]	2	4	64
34	E.f.	3	2	32
35	E.f.	4	1	16
36	E.f.	mixed		
		2	2	32
		3	1	16
		4	0.5	8
37	P.m.[b]	2	4	64
38	P.m.	3	2	32
39	P.m.	4	1	16
40	P.m.	mixed		
		2	2	32
		3	1	16
		4	0.5	8
41	E.f. + P.m.			
	E.f.	2	2	32
	P.m.	2	2	32
42	E.f. + P.m.			
	E.f.	3	1	16
	P.m.	3	1	16
43	E.f. + P.m.			
	E.f.	4	0.5	8
	P.m.	4	0.5	8
44	E.f. + P.m.	mixed		
	E.f.	2	1	16
		3	0.5	8
		4	0.025	4
	P.m.	2	1	16
		3	0.05	8
		4	0.025	4
45	Unsampled check[c]			
46	Unsampled check			
47	Sampled check[d]			
48	Sampled check			

[a] E.f.=Eocanthecona furcellata

[b] P.m.=Podisus maculiventris

[c] Unsampled check=pest populations not disturbed

[d] Sampled check=pest population disturbed when sampled

TABLE 3-3
Whole Number of Nymphs Released on September 22, 1981 (TT_2)

Plot No.	Species	Instar	Number Released (R_1) Per Foot in Row	Per Plot
17	E.f.[a]	2	8	128
18	E.f.	3	4	64
19	E.f.	4	2	32
20	E.f.	mixed		
		2	4	64
		3	2	32
		4	1	16
21	P.m.[b]	2	8	128
22	P.m.	3	4	64
23	P.m.	4	2	32
24	P.m.	mixed		
		2	4	64
		3	2	32
		4	1	16
25	E.f. + P.m.			
	E.f.	2	4	64
	P.m.	2	4	64
26	E.f. + P.m.			
	E.f.	3	2	32
	P.m.	3	2	32
27	E.f. + P.m.			
	E.f.	4	1	16
	P.m.	4	1	16
28	E.f. + P.m.	mixed		
	E.f.	2	2	32
		3	1	16
		4	0.5	8
	P.m.	2	2	32
		3	1	16
		4	0.5	8
29	Unsampled check[c]			
30	Unsampled check			
31	Sampled check[d]			
32	Sampled check			

[a] E.f.=Eocanthecona furcellata

[b] P.m.=Podisus maculiventris

[c] Unsampled check=pest populations not disturbed

[d] Sampled check=pest population disturbed when sampled

TABLE 3-4
Half Number of Nymphs Released on September 22, 1981 (TT_2)

Plot No.	Species	Instar	Number Released ($R_{\frac{1}{2}}$) Per Foot in Row	Per Plot
49	E.f.[a]	2	4	64
50	E.f.	3	2	32
51	E.f.	4	1	16
52	E.f.	mixed		
		2	2	32
		3	1	16
		4	0.5	8
53	P.m.[b]	2	4	64
54	P.m.	3	2	32
55	P.m.	4	1	16
56	P.m.	mixed		
		2	2	32
		3	1	16
		4	0.5	8
57	E.f. + P.m.			
	E.f.	2	2	32
	P.m.	2	2	32
58	E.f. + P.m.			
	E.f.	3	1	16
	P.m.	3	1	16
59	E.f. + P.m.			
	E.f.	4	0.5	8
	P.m.	4	0.5	8
60	E.f. + P.m.	mixed		
	E.f.	2	1	16
		3	0.5	8
		4	0.25	4
	P.m.	2	1	16
		3	0.5	8
		4	0.25	4
61	Unsampled check[c]			
62	Unsampled check			
63	Sampled check[d]			
64	Sampled check			

[a] E.f.=Eocanthecona furcellata

[b] P.m.=Podisus maculiventris

[c] Unsampled check=pest populations not disturbed

[d] Sampled check=pest populations disturbed when sampled

Nymphs were brushed on the topmost leaf of a soybean plant at 0.305 meter intervals on each of the 2.44 meter rows of each plot by using a hair brush. Releases were made in the early morning to avoid wind problems.

Data on percentage of defoliation and survival rate of nymphs were obtained at 10-day intervals after release. Four plants were randomly chosen from each row of each plot. Percent defoliation was estimated by observing the percent of leaf area consumed on each plant. On sampled check plots pest populations were sampled by the shake cloth-beat method using 2 shakes per plot. For unsampled check plots four plants per row were randomly chosen and all visible velvetbean caterpillar larvae were counted.

It is difficult to obtain accurate repeatable counts through direct observations of numbers of nymphs present and of estimated percent defoliation. As a consequence, the sampling error of the data was excessively large.

Yield and water content of soybeans harvested on October 19, from each of the plots, was determined within four hrs after harvesting. The number of soybean plants in each plot was also counted. For purposes of establishing yield from each plot, weight of the harvested soybeans was adjusted to an 8% moisture content.

Results and Discussion

Nymphal Survival Rate

Table 3-5 shows the percent of observed survival and estimated percent survival of released nymphs. The survival

TABLE 3-5

Eocanthecona furcellata and Podisus maculiventris

Nymphal Survival Rates in Release Plots

Plot No.	No. Nymphs Released	No. of Plants/Plot	No. of Nymphs Found on Sept. 21	Oct. 1	Oct. 5	Total	Survival Rate %*	Estimated Survival %**
1	128	53	3	6	0	9	7.0	46.6
2	64	51	3	0	1	4	6.3	38.8
3	32	60	2	0	0	2	6.3	46.9
4	112	61	2	0	0	2	1.8	13.6
5	128	56	1	2	0	3	2.3	16.4
6	64	59	0	0	0	0	0	0
7	32	38	1	2	0	3	9.4	44.5
8	112	39	0	1	0	1	0.9	4.4
9	128	70	4	0	0	4	3.1	27.3
10	64	76	0	0	2	2	3.1	29.7
11	32	35	2	0	0	2	6.3	27.3
12	112	65	0	0	2	2	1.8	14.5
17	128	69	0	5	0	5	3.9	33.7
18	64	43	0	0	2	2	3.1	16.8

TABLE 3-5-continued

Plot. No.	No. Nymphs Released	No. of Plants/Plot	No. of Nymphs Found on Sept. 21	Oct. 1	Oct 5	Total	Survival Rate %*	Estimated Survival %**
19	32	69	0	1	0	1	3.1	27.0
20	112	63	0	2	1	3	2.7	21.1
21	128	58	0	0	0	0	0	0
22	64	41	0	0	0	0	0	0
23	32	67	0	1	0	1	3.1	26.2
24	112	59	0	0	0	0	0	0
25	128	74	0	2	1	3	2.3	21.7
26	64	61	0	0	0	0	0	0
27	32	61	0	1	0	1	3.1	23.8
28	128	59	0	4	3	7	5.4	40.3
33	64	72	0	0	0	0	0	0
34	32	56	0	0	0	0	0	0

TABLE 3-5-continued

Plot No.	No. Nymphs Released	No. of Plants/Plot	No. of Nymphs Found on Sept. 21	Oct. 1	Oct. 5	Total	Survival Rate %*	Estimated Survival %**
35	16	50	2	0	0	2	12.5	78.1
36	56	52	0	0	1	1	1.8	11.6
37	64	77	0	0	0	0	0	0
38	32	60	0	0	0	0	0	0
39	16	42	0	0	0	0	0	0
40	56	60	0	0	0	0	0	0
41	64	64	0	0	0	0	0	0
42	32	62	1	1	0	2	6.3	48.4
43	16	77	0	0	0	0	0	0
44	56	83	3	0	0	3	5.4	55.6
49	64	63	0	0	0	0	0	0
50	32	49	0	0	0	0	0	0
51	16	61	0	0	0	0	0	0
52	56	69	0	1	0	1	1.8	15.4
53	64	54	0	1	0	1	1.6	10.5

TABLE 3- 5-concluded

Plot No.	No. Nymphs Released	No. of Plants/Plot	No. of Nymphs Found on Sept. 21	Oct. 1	Oct. 5	Total	Survival Rate %*	Estimated Survival %**
54	32	66	0	1	0	1	3.1	25.8
55	16	61	0	1	0	1	6.3	47.7
56	56	62	0	0	0	0	0	0
57	64	60	0	0	0	0	0	0
58	32	57	0	0	0	0	0	0
59	16	57	0	0	0	0	0	0
60	56	39	0	1	0	1	1.8	8.7

*Survival rate = $\frac{\text{total nymphs observed}}{\text{total nymphs released}} \times 100$

**Estimated survival rate = $\frac{\text{total nymphs observed x number of plants within plot}}{\text{number of plants sampled (8) x total nymphs released}} \times 100$

rate was established by counting the number of nymphs observed in the field divided by the total number of nymphs released. The highest survival rate was 12.5% at plot 35, where 4th instars of E. furcellata were released. The estimated survival rate was established by counting the nymphs observed in a plot divided by the number of replications (i.e., 8) times the total number of plants per plot. Again the highest of the estimated survival rates was 78.1% at plot 35, where the fourth instars of E. furcellata were released.

Because no cloth-beating sampling method was allowed for purposes of the survival rate investigation, the data presented here provide only index values representative of nymphal survival. Actual survival rate data would have required special sampling procedures and more time than was available.

No nymphs of either species were observed to move among plots. However, within the plots it appeared that nymphs moved between rows though no direct evidence of such movements was obtained. There was no scarcity of prey in the field after release of the nymphs. In an unrelated test, nymphs of both species released in a potato field were observed to move as much as 1.22 meters (umpublished data by author). This relative lack of mobility of the asopine nymphs is an important characteristic as it relates to their

possible use in suppression of velvetbean caterpillar populations. Once placed in the field they will remain there until they become adults. Most of the other predators are much more mobile and their action is therefore less predictable; also, most other predators, e.g. nabids, are more difficult to handle than are the asopine nymphs. For many species no method of mass rearing has been developed that would enable them to be used in inundative programs. Certainly no equally effective predator can be reared at a relatively lower cost.

Defoliation

Nymphs of both species were released on two different dates, September 11 (TT_1) and September 22 (TT_2), and at two different levels of numbers for each release date, i.e., "whole" numbers (R_1) and "half" numbers ($R_{\frac{1}{2}}$). Results of defoliation in percentages are shown in Tables 3-6 and 3-9.

In general, defoliation percentages between release plots and the sampled check or unsampled check plots were not significantly different at the time of the first release. However, significant differences were present on October 1 as shown in Table 3-10.

Table 3-10 shows that, irrespective of R_1 or $R_{\frac{1}{2}}$, on TT_1 there were significant differences between release plots and check plots on October 1, while on TT_2 there was a significant difference for TT_2R_1 on October 1, but for $TT_2R_{\frac{1}{2}}$, a significant difference was not observed until October 5.

TABLE 3- 6
Mean Percent Defoliation for Each Plot Where "Whole Number" Releases (R_1) were Made on September 11 (TT_1)

Plot No.	September 11	September 21	October 1	October 5
1	7	15	60	100
2	5	10	40	100
3	5	10	30	100
4	5	10	30	100
Mean	5.50	11.25	40.00	100.00
5	5	10	30	95
6	5	10	30	95
7	5	15	45	100
8	5	10	45	100
Mean	5.00	11.25	37.50	97.50
9	5	10	40	100
10	5	10	30	100
11	5	10	30	100
12	5	10	30	100
Mean	5.00	10.00	32.50	100.00
13	5	20	70	100
14	5	15	60	100
Mean	5.00	17.50	65.00	100.00
15	5	15	60	100
16	5	10	70	100
Mean	5.00	12.50	65.00	100.0

TABLE 3-7
Mean Percent Defoliation Where "Whole Number" Releases were Made on September 22 (TT_2)

Plot No.		% Defoliation			
		September 11	September 21	October 1	October 5
17		5	10	60	100
18		5	10	65	100
19		2	5	20	70
20		7	20	80	100
	Mean	4.75	11.25	56.25	92.50
21		4	10	70	90
22		5	15	65	100
23		5	10	90	95
24		5	15	65	100
	Mean	4.75	12.50	72.50	96.25
25		5	10	25	100
26		5	10	45	90
27		5	10	30	90
28		5	10	40	100
	Mean	5.00	10.00	35.00	95.00
29		5	10	100	100
30		5	10	100	100
	Mean	5.00	10.00	100.00	100.00
31		5	10	100	100
32		5	10	100	100
	Mean	5.00	10.00	100.00	10.00

TABLE 3-8
Mean Percent Defoliation for Each Plot Where "Half Number" Releases were Made on September 11 (TT_1)

Plot No.	% Defoliation			
	September 11	September 21	October 1	October 5
33	6	15	100	100
34	5	10	50	90
35	5	10	35	90
36	5	15	85	100
Mean	5.25	12.50	67.50	95.00
37	5	10	85	100
38	5	10	55	100
39	5	10	15	40
40	5	15	30	100
Mean	5.00	11.25	46.25	85.00
41	9	20	55	100
42	5	15	65	100
43	10	20	75	100
44	5	10	15	80
Mean	7.25	16.25	52.50	95.00
45	6	20	75	100
46	8	20	75	100
Mean	7.00	20.00	75.00	100.00
47	5	15	100	100
48	6	20	60	95
Mean	5.50	17.50	80.00	97.50

TABLE 3-9
Mean Percent of Defoliation where "Half Number" Releases were Made on September 22 (TT_2)

Plot No.		% Defoliation September 11	September 21	October 1	October 5
49		5	10	20	35
50		5	15	30	90
51		5	15	20	60
52		4	10	15	60
	Mean	4.75	12.50	21.25	61.25
53		5	10	30	85
54		5	10	25	70
55		4	10	30	50
56		5	10	30	50
	Mean	4.75	10.00	28.75	72.50
57		4	10	20	70
58		4	10	35	80
59		5	10	12	70
60		4	10	15	70
	Mean	4.25	10.00	20.50	72.50
61		4	10	30	80
62		4	15	25	80
	Mean	4.00	12.50	27.50	80.00
63		5	10	30	90
64		4	10	40	90
	Mean	4.50	10.00	35.00	92.50

TABLE 3-10

Test of Significant Difference between Asopine Predator Release Plots and Sampled Check and Unsampled Check Plots on Two Different Release Dates (TT_1 and TT_2) and Two Different Release Numbers (R_1 and $R_{\frac{1}{2}}$)

	z Value			
Release Date	September 11	September 21	October 1	October 5
TT_1 R_1	-0.04 NS	0.63 NS	2.83*	0.51 NS
TT_1 $R_{\frac{1}{2}}$	0.09 NS	0.38 NS	2.22**	1.40 NS
TT_2 R_1	0.03 NS	-0.19 NS	4.70**	1.35 NS
TT_2 $R_{\frac{1}{2}}$	-0.06 NS	0.07 NS	0.87 NS	1.93**

*P 0.05 Significance
**P 0.01 significance

TT_1=September 11 release date
TT_2=September 22 release date
R_1="Whole number" of nymphs
$R_{\frac{1}{2}}$="Half number" of nymphs

Yield and Water Content

Table 3-11 shows the yield and percent of water content of each plot. Table 3-12 shows the mean yield and the mean percent of water content based on the age differential of E. furcellata and P. maculiventris and their combinations. The results show that E. furcellata plus P. maculiventris release plots produced the highest yield and the sampled check plots had the lowest yield (Table 3-13).

The mean yield from the plots in which the asopine nymphs were released was significantly higher than that of the sampled check or of unsampled check plots (P=0.05) (Table 3-13).

No significant difference was detected among yields related to species released nor between sampled check and unsampled check plots at P=0.05 levels (Table 3-13).

When data from plots receiving different ages and numbers of asopine nymphs were combined results show that plots where E. furcellata plus P. maculiventris nymphs were released on September 11 had the highest mean yield while the sampled and unsampled check plots for the same date had the lowest (Table 3-14). There was no significant (P=0.05) difference between plots receiving nymphs of E. furcellata and those receiving nymphs of P. maculiventris. However, the difference between plots receiving nymphs of E. furcellata plus P. maculiventris and those receiving nymphs of P. maculiventris was significant (Table 3-14).

TABLE 3-11
Yield and Water Content of Soybeans Harvested from Each Plot

Plot No.	Gross Weight (gm)	Water Content (%)	Adjusted* Weight (gm)
1	947	10.2	924
2	1254	8.9	1242
3	1228	8.8	1217
4	1359	8.9	1346
5	792	11.4	763
6	1210	8.5	1194
7	994	9.4	979
8	722	9.5	710
9	1278	9.2	1261
10	1117	9.5	1099
11	1137	8.7	1128
12	1218	8.2	1215
13	1039	8.2	1037
14	655	8.1	655
15	913	8.2	911
16	768	8.3	765
17	1160	9.1	1146
18	1046	9.0	1035
19	1030	9.7	1011
20	921	8.9	912
21	1048	9.1	1035
22	968	8.6	962
23	1105	9.2	1091

TABLE 3-11-continued

Plot No.	Gross Weight (gm)	Water Content (%)	Adjusted* Weight (gm)
24	1238	8.6	1230
25	1159	8.7	1150
26	1128	8.6	1121
27	1111	8.3	1107
28	1103	8.7	1095
29	1002	8.1	1001
30	798	8.2	796
31	770	8.1	769
32	826	8.2	824
33	1103	10.5	1073
34	1209	9.9	1184
35	1258	10.0	1231
36	1079	10.2	1053
37	1246	10.2	1216
38	1195	9.3	1178
39	903	11.2	872
40	1183	8.7	1174
41	1063	10.1	1039
42	1135	10.4	1105
43	1313	9.8	1287
44	1317	10.3	1284
45	780	8.2	778
46	959	8.3	956
47	901	8.5	896

TABLE 3-11-concluded

Plot No.	Gross Weight (gm)	Water Content (%)	Adjusted* Weight (gm)
48	903	8.4	899
49	713	14.4	663
50	937	9.7	920
51	1210	10.6	1176
52	1268	9.8	1243
53	1198	9.9	1173
54	1335	9.4	1315
55	1063	10.3	1036
56	1200	8.9	1188
57	1237	10.0	1210
58	944	9.5	929
59	1028	11.1	993
60	1044	10.0	1021
61	836	8.2	834
62	509	8.3	507
63	530	8.5	527
64	896	8.5	891

*Adjusted Weight=weight of soybeans at 8% water content

TABLE 3-12
The Yield and Water Content of Plots Receiving Different Age Nymphs of Each Species, Combination of Species, and Combined Dates

Species	Instar	Mean Weight (gm)	Mean Water Content (%)
E. furcellata	mixed	1138.5	9.4
	2	951.5	11.0
	3	1095.2	9.4
	4	1158.7	9.8
	mean	1086.0	9.93
P. maculiventris	mixed	1075.5	8.9
	2	1046.7	10.1
	3	1162.2	9.0
	4	994.5	10.0
	mean	1069.75	9.52
E. furcellata + P. maculiventris	mixed	1153.7	9.3
	2	1165.0	9.5
	3	1063.4	9.5
	4	1123.7	9.5
	mean	1126.5	9.46
Unsampled check[a]		820.7	8.23
Sampled check[b]		807.0	8.38
	mean	813.88	8.31
	mixed	1122.58	9.24
	2	1054.42	10.23
	3	1107.0	9.28
	4	1092.33	9.78
	$\bar{x}$ all ages	1094.08	9.63

[a] Unsampled check=pest populations not disturbed

[b] Sampled check=pest populations disturbed when sampled

TABLE 3-13
The Mean Yield as Influenced by Species of Predator when Data for Release Date, Age of Nymphs and Number Released are Combined

Species	Yield (gm)
E. furcellata + *P. maculiventris*	1127.7 a
E. furcellata	1086.0 a
P. maculiventris	1096.7 a
Unsampled check[a]	820.7 b
Sampled check[b]	807.0 b

Means with the same letter are not significantly different according to Duncan's multiple range test (P=0.05)

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[a] Unsampled check=pest populations not disturbed

[b] Sampled check=pest populations disturbed when sampled

TABLE 3-14
The Mean Yield of Different Species Treatment Plots for Releases Made on September 11 Irrespective of Age and Number of Released Nymphs

Species	Yield (gm)
E. furcellata + P. maculiventris	1177.2 a
E. furcellata	1158.7 ab
P. maculiventris	1010.7 bc
Sampled check[a]	861.0 c
Unsampled check[b]	856.5 c

Means with the same letter are not significantly different according to Duncan's multiple range test (P=0.05).

[a]Sampled check=pest populations disturbed when sampled

[b]Unsampled check=pest populations not disturbed

Tables 3-15 and 3-17 also show that the difference between yield of plots where the releases were made September 11 and those where releases were made on September 22 is significant at the P=0.01 level. The real significance of difference between dates is indicated by the similar difference in yield of the sampled and unsampled check plots for these dates (Tables 3-14 and 3-16).

The Duncan multiple range test (Table 3-14) indicates no significant differences among yields from E. furcellata release plots and those where both E. furcellata and P. maculiventris were released, nor between the E. furcellata and the P. maculiventris release plots. The difference between the plots receiving P. maculiventris and the sampled and unsampled check plots failed to show significance at the P=0.05 level (Table 3-14). For reasons not clearly understood, it appears that a release of nymphs of both species is more effective than release of equal numbers of either species alone.

On the second release date, September 22 (TT_2), significant differences were again apparent between the released and check plots (Tables 3-16 and 3-17).

The Duncan multiple range tests showed that the differences in yield from plots where nymphs were released, and those from the sampled and unsampled check, were statistically significant at the P=0.05 level. However, the differences

TABLE 3-15
Analysis of Variance for Yield as Related to Species of Predator Released on September 11 Irrespective of Age and Number of Released Nymphs

Source	df	SS	MS	F-value	PR>F
treatment	4	359430.7	89857.4	4.19	0.0108**
error	23	493349.0	21440.0		

TABLE 3- 16
Mean Yield of Different Species Treatment Plots when Releases were Made on September 22 Irrespective of Age and Number of Released Nymphs

Species	Yield (gm)
E. furcellata	1013.2 a
E. furcellata + P. maculiventris	1078.2 a
P. maculiventris	1128.7 a
Sampled check[a]	753.0 b
Unsampled check[b]	785.0 b

Means with the same letter are not significantly different according to the Duncan multiple range test (Alpha=0.05).

[a]Sampled check=pest populations disturbed when sampled

[b]Unsampled check=pest population not disturbed

TABLE 3 -17
Analysis of Variance for Yield as Related to Species of Predator Released on September 22 Irrespective of Age and Number of Nymphs Released

Source	df	SS	MS	F-value	PR>F
Treatment	4	372389.4	93097.3	5.05	0.0045**
Error	23	424152.5	18441.4		

between plots receiving E. furcellata, P. maculiventris, and E. furcellata plus P. maculiventris nymphs of different age and number were not significant. Neither was the difference between sampled check and unsampled check plots significant (Table 3-16). When yield data for the two release dates (TT_1 and TT_2) were compared and statistically analyzed, differences between release treatments were not significant, nor was the yield of the two types of check plots significantly different (Tables 3-18 and 3-23).

Percent of Soybean Water Content

The mean percent of water content of treatment plots involving different age of nymphs, species, and treatment date were not significantly different (Tables 3-24 and 3-25).

There is no evidence showing that the percent of water content was significantly different on the first date of release and the second date of release in E. furcellata release plots, P. maculiventris release plots, E. furcellata and P. maculiventris release plots, sampled and unsampled check plots at a 0.05 level (Tables 3-26 and 3-35).

No significant difference was detected in soybean percent of water content related to asopine species released. Neither was there a significant difference between sampled check and unsampled check plots (P=0.05) (Table 3-36). However, the mean percent water content of soybeans harvested from the asopine species released plots was significantly higher than that from the sampled check or unsampled

TABLE 3- 18
Analysis of Variance for Yield from Plots in Which *E. furcellata* was Released on September 11 and September 12

Source	DF	SS	MS	F Value	PR>F
Treatment	1	84681	84681	3.3	0.0926 NS
Error	14	363883	25992		

TABLE 3-19
The Mean Yield from E. furcellata Plots as Determined by Release Date

Release Date	Yield (gm)
September 11 (TT_1)	1158.7 a
September 22 (TT_2)	1013.2 a

Means with the same letter are not significantly different according to Duncan's multiple range test (P=0.05).

TABLE 3-20
Analysis of Variance for the Yield from P. maculiventris Release Plots as Determined by Release Date

Source	df	SS	MS	F-value	PR>F
Treatment	1	39204	39204	4.5	0.0531 NS
Error	14	123023	8787.4		

TABLE 3-21
The Mean Yield from P. maculiventris Release Plots as Determined by Release Date

Release Date	Yield (gm)
September 11 (TT_1)	1010.7 a
September 22 (TT_2)	1128.7 a

Means with the same letter are not significantly different according to Duncan's multiple range test (P=0.05).

TABLE 3-22
Analysis of Variance for the Yield from the
E. furcellata with P. maculiventris Release Plots as
Determined by Release Dates

Source	df	SS	MS	F-value	PR>F
Treatment	1	55696	55696	1.9	0.1841 NS
Error	14	399453	28532		

TABLE 3-23
The Mean Yield from the E. furcellata with P. maculiventris Release Plots as Determined by Release Date

Release Date	Yield (gm)
September 11 (TT_1)	1177.2 a
September 22 (TT_2)	1078.2 a

Means with the same letter are not significantly different according to Duncan's multiple range test (P=0.05).

TABLE 3-24
Analysis of Variance for Percent Water Content of Soybeans From Plots Where Nymphs were Released on September 11 Irrespective of Age and Number and Species

Source	df	SS	MS	F-value	PR>F
Treatment	4	6.5	1.6	2.4	0.079 NS
Error	23	15.5	0.7		

TABLE 3-25
Analysis of Variance for Percent Water Content of Soybeans from Plots where Nymphs were Released on September 22 Irrespective of Age, Number, and Species

Source	df	SS	MS	F-value	PR>F
Treatment	4	9.8	2.4	1.8	.17 NS
Error	23	31.8	1.4		

TABLE 3-26
Analysis of Variance for the Percent Water Content of Soybeans from Plots where E. furcellata was Released on September 11 and 22 as Treatment

Source	DF	SS	F-value	PR>F
Treatment	1	0.8	0.4	0.52 NS
Error	14	25.8		

TABLE 3-27
The Mean Percent Water Content of Soybean Harvested from the E. furcellata Release Plots as Determined by Release Date

Release Date	% Water
September 11	9.7 a
September 22	10.2 a

Means with the same letter are not significantly different according to Duncan's multiple range test (P=0.05).

TABLE 3-28
Analysis of Variance for Percent Water Content of Soybeans Harvested from Plots where P. maculiventris was Released on September 11 and 22 as Treatment

Source	DF	SS	F-Value	PR>F
Treatment	1	1.1	1.5	0.2479 NS
Error	14	10.6		

TABLE 3-29
The Mean Percent of Water Content of Soybean Harvested from the P. maculiventris Release Plots as Determined by Release Date

Release Date	% Water
September 11	9.8 a
September 22	9.3 a

Means with the same letter are not significantly different according to Duncan's multiple range test (P=0.05).

TABLE 3-30
Analysis of Variance for Percent Water Content of Soybeans Harvested from Plots in Which E. furcellata and P. maculiventris were Released on September 11 and 22 as Treatment

Source	Df	SS	F-value	PR>F
Treatment	1	0.1	0.1	0.7163 NS
Error	14	10.8		

TABLE 3-31
The Mean Percent Water Content of Soybeans Harvested from *E. furcellata* and *P. maculiventris* Release Plots as Determined by Release Date

Release Date	% Water
September 11	9.5 a
September 22	9.4 a

Means with the same letter are not significantly different according to Duncan's multiple range test. ($p=0.05$)

TABLE 3-32
Analysis of Variance for the Percent Water Content of Soybean Harvested from Sampled Check Plots (P=0.05)

Source	Df	SS	F-value	PR>F
Treatment	1	0.0025	0.08	0.8075 NS
Error	2	0.0650		

TABLE 3-33
The Mean Percent Water Content of Soybeans Harvested from Sampled Check Plots as Determined by Release Date

Release Date	% Water
September 11	8.4 a
September 22	8.4 a

Means with the same letter are not significantly different according to Duncan's multiple range test (P=0.05).

TABLE 3-34
Analysis of Variance for the Percent Water Content of Soybeans Harvested from Unsampled Plots

Source	Df	SS	F-value	PR>F
Treatment	1	0.0025	1.00	0.4226 NS
Error	2	0.0050		

TABLE 3-35
The Mean Percent Water Content of Soybean Harvested from the Unsampled Check

Date	% Water
September 11	8.3 a
September 22	8.2 a

Means with the same letters are not significantly different according to Duncan's multiple range test (P=0.05).

TABLE 3-36
The Mean Percent Water Content of Soybean Harvested from Plots as Influenced by Asopine Species when Age of Nymphs and Number Released are Combined (P=0.05)

Species	% Water Release on Sept. 11	Release on Sept. 22
E. furcellata	9.70 a	10.15 a
P. maculiventris	9.78 a	9.25 a
E. furcellata and P. maculiventris	9.53 a	9.36 a
Sampled check[a]	8.40 b	8.35 b
Unsampled check[b]	8.25 b	8.20 b

Means with the same letter on the same column are not significantly different according to Duncan's multiple range test (P=0.05).

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[a]Sampled check=pest populations disturbed when sampled

[b]Unsampled check=pest populations not disturbed

check plots. The higher percent water content of soybean reflected the fact that soybean plants remained green longer due to reduced levels of defoliation.

The highest percent of water content of soybeans from 2nd instar nymph release plots was with E. furcellata; from 3rd instar nymph release plots was E. furcellata and P. maculiventris; from 4th instar nymph release plots was P. maculiventris; and from mixed instar nymph release plots was E. furcellata (Table 3-37). However, after the Duncan multiple range test, no significant difference is indicated among any of the plots. The percent of water content of soybeans from sampled check and unsampled check plots was 8.4 and 8.2, respectively (Table 3-36). These results suggested that no matter what species of asopine nymphs were released the soybean leaves or plants in the release plots were kept green longer than sampled or unsampled check plots. Additional studies are needed to define the critical time during which leaf area is correlated with yield. Once that critical time is defined, releasing asopine nymphs before that critical time might increase yield.

Percent of water content was not significantly different in soybeans from 2nd, 3rd, 4th, or mixed instars from E. furcellata release plots and E. furcellata and P. maculiventris release plots (Table 3-38). But from P. maculiventris release plots the percent of water content of

TABLE 3-37
The Mean Soybean Percent of Water Content as Influenced by Species and Age of Nymphs Released

Instar	Species	% Water
2	E. furcellata	11.05 a
	P. maculiventris	10.15 a
	E. furcellata and P. maculiventris	9.50 a
3	E. furcellata and P. maculiventris	9.50 a
	E. furcellata	9.38 a
	P. maculiventris	8.95 a
4	P. maculiventris	10.03 a
	E. furcellata	9.83 a
	E. furcellata and P. maculiventris	9.48 a
mixed	E. furcellata	9.45 a
	E. furcellata and P. maculiventris	9.30 a
	P. maculiventris	8.93 a

Means with the same letter are not significantly different according to Duncan's multiple range test (P=0.05).

TABLE 3-38
The Mean Percent Water Content of Soybean Harvested from Plots as Influenced by Species and Instar Released

Instar	Species A* % Water	Species B** % Water	Species Combined % Water
2	11.05 a	10.15 a	9.50 a
3	9.38 a	8.95 b	9.50 a
4	9.83 a	10.03 ab	9.48 a
mixed	9.45 a	8.93 b	9.30 a

*A=E. furcellata
**B=P. maculiventris

Means following the same letter in the same column are not significantly different according to the Duncan's multiple range test (P=0.05).

soybeans from the 2nd instar release plots is significantly higher than 3rd instar release plots, and also higher than mixed instar release plots (Table 3-38).

The release of asopine species in soybeans for suppression of velvetbean caterpillar pest population has many potential advantages. First, velvetbean caterpillars are directly captured and consumed. Second, velvetbean caterpillars often drop to the ground due to escape response brought about by asopine's stylet contact. Once velvetbean caterpillars fall to the ground probability of predation may be increased before they return to the plant. When the caterpillars move back to the plant they are also subject to the hazard of being killed by predators that inhabit shaded areas of soybean plants. Also, time is required for the velvetbean caterpillar to return to the leaves; if the delay coincides with the critical time of soybean pod set, it may result in increased soybean yield. Third, nymphal development for both species requires approximately 20 days on soybean in north Florida in August. Activity of the nymphs can be expected in the release area for about 20 days. No other predator can be utilized in such manner and no registered insecticide can provide protection for 20 days. Fourth, release number can be regulated based on larval population or population predictions and thus simulating the kind of numerical response

that is normally encountered in situations where a nature enemy in nature is able to regulate a host population at a very low level. Fifth, asopine nymphs can be easily mass reared at relatively low cost. Sixth, dispersal of nymphs does not exceed 1.22 meters. The predatory activity of nymphs is limited to the release area until adults emerge and disperse.

As anticipated there was some difference in defoliation of the asopine bugs release plots and sampled or unsampled check plots. For reasons of time it was not possible to measure degree of defoliation by other than direct visual observation. While this provided estimated values any measure of difference between plots was highly subjective. However, it was noted that beans on more heavily defoliated plants were ripening more rapidly than those with a lesser degree of defoliation. It appeared that a measure of the water content of beans harvested from each plot would provide an indirect but objective measure of defoliation. Following analysis of the harvested beans for water content, those from plots where asopine bugs were released (combined ages, species and dates) averaged 1.32% higher than the soybeans from the unsampled and sampled check plots.

When adjusted for water content at 8%, the mean yield of soybeans from the release plots was 280 gm greater than from the sampled and unsampled check plots. On the basis of this difference in yield which must be attributed to protection of foliage by release bugs, it is possible to

calculate benefits. However, it should be noted that these benefits are based on yield of small plots, i.e. 3.72 square meters (or 40 square feet), that were well fertilized and irrigated as needed. Assuming 3.72 square meters as the area of each plot and 280 gm as the mean weight difference between asopine bugs released plots and sampled and unsampled check plots, and figured at the current soybean market price of $0.25 per kg (or $6.70 per bushel) (September 1982 Delivery), the benefit to the grower resulting from the release of the asopine bugs would amount to $188.22 per hectare (or $76.23 per acre).

On the debit side there is the cost of the released bugs and cost of placing them in the field. Released at the maximum number of this experiment (128 nymphs per plot), 344,178 nymphs would be required per hectare (or 139,392 nymphs per acre). Since the cost of producing the released nymphs was approximately $0.96 per 1000, then per hectare cost would be $330.41 (or $133.82 per acre). Added to this would be cost of labor required to place the asopine bugs in the field. Conservatively estimated this would entail 8 hours work of three people which if figured at $3.50 per hour for wage would add another $84 per hectare cost, or a total of 414.41 (or $167.81 per acre), and would indicate a net loss of $226.19 per hectare (or $91.58 per acre).

Admittedly many of the above figures are estimated and with large scale production the cost of producing the

asopine nymphs would be greatly reduced. No doubt means could also be devised to enable them to be released at much less cost per hectare; however, for purposes of crop protection alone control of V.B.C. through augmentation of the predator population is far from competitive with chemical insecticides. At the same time it should be noted that the augmentation of predators method does not incur hidden costs such as degradation of the environment, induction of secondary pest outbreaks, pest resurgence and other adverse effects associated with insecticides.

CHAPTER FOUR
NATURAL ENEMIES OF EOCANTHECONA FURCELLATA (WOLFF) AND PODISUS MACULIVENTRIS (SAY)

Introduction

Pentatomid egg masses are subject to attack by many parasites, namely Telenomus mormideae Costa Lima, Telenomus utahensis Ashmead, Telenomus chloropus Thomson, Trissolcus basalis (Wallaston), Trissolcus euschisti (Ashmead), Trissolcus grandis (Thomson), and others.

Mukerji and LeRoux (1964) found that egg masses of P. maculiventris were parasitized by undetermined chalcids. Undetermined acarine predators were associated occasionally with egg masses, nymphs, and adults of P. maculiventris in the laboratory.

Girault (1907) reported that egg masses of P. maculiventris were parasitized by four hymenopterous species, namely Telenomus podisi Ashmead, T. dimmocki Ashmead, T. thyantea Ashmean, and Trissolcus podisi (Ashmead).

. Jubb and Watson (1971) studied the parasitization capabilities of Telenomus utahensis on the pentatomids Chlorochroa uhleri (Stal) and C. sayi (Stal) under laboratory conditions in Arizona. They found that the highest percentage of parasitism occurred when the eggs were

parasitized while they were less than 24 hrs old. They also found that temperature was a very important factor affecting rates of parasitism.

In the United States, little has been done to investigate the action of egg parasites in natural regulation of asopine pentatomids. Those reported to attack P. maculiventris are listed in Table 4-1.

During 1981, parasitization of P. maculiventris and E. furcellata eggs as observed in the field and preliminary studies were undertaken in the laboratory. These were conducted in order to learn if there was any significant difference in the vulnerability of the native P. maculiventris and the introduced E. furcellata to parasitization or predation.

Materials and Methods

Egg Stage

One E. furcellata egg mass and one P. maculiventris egg mass, each less than 24 hrs old, were selected for exposure to Trissolcus basalis. Each was laid on slips of paper toweling which were then placed in a cotton-stoppered test tube. The test tube contained about 200 recently emerged T. basalis. After two days the egg masses were removed and each placed in another cotton-stoppered test tube containing a section of green bean, which provided a desirable level of humidity inside the test tube. The green bean was changed about every second day. Four replications

TABLE 4-1
Species that Parasitize Podisus maculiventris (Say)

Family	Species	Reference
Scelionidae	Telenomus thyantea Ashm.	Ashmead 1893 Girault 1907
	Telenomus podisi Ashm.	Ashmead 1893 Kirkland 1898 Girault 1907 Muesebeck et al. 1951 Krombein et al. 1979 Yeargan 1979, 1980 Buschman & Whitcomb 1980
	Telenomus dimmocki Ashm.	Dimmock 1897 Girault 1907 Krombein et al. 1979
	Telenomus spp., Gryon spp.	Buschman & Whitcomb 1980

TABLE 4-1-continued

Family	Species	Reference
Scelionidae	Trissolcus euschisti (Ashm.)	Yeargan 1979
	Trissolcus podisi (Ashm.)	Riley & Howard 1891 Ashmead 1893 Kirkland 1898 Girault 1907 Muesebeck et al. 1951 Krombein et al. 1979
	Trissolcus basalis (Wollaston)	Jones 1979 Buschman & Whitcomb 1980 Author observation
	Trissolcus spp.	Buschman & Whitcomb 1980
	Hadronotus spp.	Pott 1891
Encyrtidae	Ooencyrtus spp.	Yeargan 1979

TABLE 4-1-concluded

Family	Species	Reference
Eupelmidae	Anstatus spp.	Buschman & Whitcomb 1980
Chalcicidae	unidentified species	Mukerji & LeRoux 1965
Tachinidae	Cylindromyia fumipennis (Bigot)	Buschman & Whitcomb 1980
	Hemyda aurata Robineau-Desvoidy	Buschman & Whitcomb 1980
	Trichopoda lanipes (Fabricius)	Fatting 1949 Coppel & Jones 1964
Astatidae	Astata unicolor Say	Evans 1957

were set up and observed for two weeks. The egg masses were held at 26 ± 1°C with a photoperiod of 14:10 L:D. The tests were conducted during April 1981. In addition, 12 egg masses each of E. furcellata and P. maculiventris were exposed to field parasitization. Eggs were not more than 24 hrs old and were laid on paper toweling. When placed in the field, one egg mass of each species was attached by means of a pin to the underside of a leaf of various plants in the Organic Gardens area of the University of Florida campus at Gainesville. The 24 egg masses were exposed May 20, 1981, on leaves distributed over a garden area of about 2 hectares. On August 31 this test was repeated at the Agricultural Research and Education Center at Quincy, Florida. In this test the egg masses were exposed by placing them on the undersides of soybean leaves in a 8.1 hectares soybean field. All egg masses were removed after two days of exposure, and each placed in an appropriately labeled 3 cm x 20 cm test tube. They were then held under conditions identical to those described for the laboratory test.

Nymphal Stages

Direct observations were made in the soybean field in Quincy. As part of the research on comparative efficacy of P. maculiventris and E. furcellata, two randomized observations were made in each of the 64 release plots at 10-day intervals following the release of nymphs of the two

asopine species. The big-eyed bug, Geocoris punctipes (Say), and the damsel bug, Tropiconabis capsiformis (Germar), were captured by net and carefully transferred to petri dishes (1.5 cm deep, 9 cm diameter) for close observation in the laboratory. Nymphs of the two asopine species were added to the petri dish as potential prey. A green bean was placed in each petri dish as a water source. The ratio between big-eyed bugs or damsel bugs and 2nd instar asopine nymphs was 1:1, 1:2, and 1:4 in each petri dish. Four replications were observed. Third, fourth, and fifth instar nymphs of both asopine species were tested separately in the same way.

Results and Discussion

Egg Stage

All egg masses of both E. furcellata and P. maculiventris exposed in the laboratory to T. basalis were parasitized. The results are shown in Table 4-2.

In the field test, one of the 12 E. furcellata egg masses and one of the 12 P. maculiventris egg masses were parasitized by T. basalis. The results are shown in Table 4-3.

Nymph Stage

Second instar nymphs of both species were observed to be attacked by the nymphal and adult stages of the lygaeid big-eyed bug, G. punctipes, and the nabid damsel bug,

TABLE 4-2
Eggs of Eocanthecona furcellata and Podisus maculiventris Exposed in the Laboratory to Parasitization by Trissolcus basalis

Species	Egg Mass	No. of Eggs	Parasitized	Percent of Parasitism
E. furcellata	1	54	54	100
	2	73	73	100
	3	79	78	98.7
	4	68	65	95.6
$\bar{x}$		68.8	67.5	98.2
P. maculiventris	1	32	32	100
	2	29	27	93.1
	3	41	40	97.6
	4	38	37	97.4
$\bar{x}$		35.0	34.0	97.1

TABLE 4-3
Eggs of Eocanthecona furcellata and Podisus maculiventris
Exposed in the Field to Parasitization by
Trissolcus basalis

Location	Eocanthecona furcellata Number of observation	eggs	parasitized	% parasitism	Podisus maculiventris Number of eggs	parasitized	% parasitism
Organic Garden (UF)	1	93	0	0	46	0	0
	2	81	0	0	52	0	0
	3	85	0	0	49	0	0
	4	74	0	0	44	0	0
	5	77	0	0	42	0	0
	6	69	68	98.6	53	53	100
$\bar{x}$		79.8	11.3	14.2	47.7	8.8	18.5
Quincy AREC	7	72	0	0	41	0	0
	8	76	0	0	29	0	0
	9	84	0	0	36	0	0
	10	71	0	0	45	0	0
	11	75	0	0	50	0	0
	12	79	0	0	48	0	0

TABLE 4-3-continued

Location	Eocanthecona furcellata				Podisus maculiventris		
	Number of				Number of		
	obser-vation	eggs	para-sitized	% para-sitism	eggs	para-sitized	% para-sitism
$\bar{x}$		76.2	0.0	0.0	41.5	0.0	0.0

T. capsiformis, in the soybean field. These findings were confirmed in the laboratory. The results are shown in Tables 4-4 - 4-7. The nymphal stages of big-eyed bugs and damsel bugs were killed by the adults and 3rd, 4th, and 5th instar nymphs of E. furcellata and P. maculiventris. The results are shown in Tables 4-8 - 4-11. In no case was the adult stage of either the big-eyed bug or the damsel bug killed by adults or nymphs of either asopine species. Second and third nymphal stages of both asopine species were preyed upon in the soybean field by undetermined species of araneid spiders.

In the present studies, only one of each set of 12 egg masses was parasitized by T. basalis. While this is evidence that both asopine species, P. maculiventris and E. furcellata, were hosts of T. basalis, the numbers are too small to provide a reliable indication of field parasitism or possible host preferences of the parasite. At least four plant feeding species of pentatomid stinkbugs were present in the soybean field at Quincy, namely Acrosternum hilare (Say), Euschistus servus (Say), E. tristigmus (Say), and Nezara viridula (L.). All are known hosts of T. basalis and were no doubt the source of the females that oviposited in the intentionally exposed asopine egg masses. No naturally deposited asopine egg masses were found to be parasitized in the Quincy field.

TABLE 4-4
Predation by the Nymphs of Geocoris punctipes
on 2nd Instar Focanthecona furcellata

Observation	Number of G. punctipes	Number of E. furcellata	No. E. furcellata Nymphs Killed on Day 1	No. E. furcellata Nymphs Killed on Day 2
1	1	1	1	
2	1	1	1	
3	1	1	1	
4	1	1	1	
5	1	2	2	
6	1	2	1	1
7	1	2	2	
8	1	2	2	
9	1	4	2	1*
10	1	4	2	2
11	1	4	1	2**
12	1	4	2	2

*G. punctipes was killed by E. furcellata on 4th day.

**G. punctipes died on 3rd day.

TABLE 4-5
Predation by the Nymphs of Reduviolus roseipennis
on 2nd Instar E. furcellata

Observation	Number of R. roseipennis	Number of E. furcellata	No. E. furcellata Nymphs Killed on Day 1	Day 2
1	1	1	1	
2	1	1	1	
3	1	1	1	
4	1	1	1	
5	1	2	2	
6	1	2	2	
7	1	2	2	
8	1	2	2	
9	1	4	2	2
10	1	4	2	2
11	1	4	3	1
12	1	4	1	2*

*R. roseipennis killed by E. furcellata on 4th day

TABLE 4-6
Predation by the Nymphs of Geocoris punctipes
on the 2nd Instar of P. maculiventris

Observation	Number of G. punctipes	Number of P. maculiventris	No. P. maculiventris Nymphs Killed on Day 1	No. P. maculiventris Nymphs Killed on Day 2
1	1	1	1	
2	1	1	1	
3	1	1	1	
4	1	1	1	
5	1	2	2	
6	1	2	2	
7	1	2	2	
8	1	2	2	
9	1	4	3	1
10	1	4	2	2
11	1	4	2	2
12	1	4	2	2

TABLE 4-7
Predation by the Nymphs of Reduviolus roseipennis
on 2nd Instar P. maculiventris

Observation	Number of R. roseipennis	Number of P. maculiventris	No. P. maculiventris Nymphs Killed on Day 1	Day 2
1	1	1	1	
2	1	1	1	
3	1	1	1	
4	1	1	1	
5	1	2	2	
6	1	2	2	
7	1	2	2	
8	1	2	2	
9	1	4	2	2
10	1	4	2	2
11	1	4	2	2
12	1	4	2	2

TABLE 4-8
Predation by P. maculiventris Nymphs
on Nymphs of Reduviolus roseipennis

Observation	P. maculiventris Instar	No. of Nymphs	No. of R. roseipennis Nymphs	No. R. roseipennis Nymphs Killed on Day 1
1	3	1	1	1
2	3	1	1	1
3	3	1	2	2
4	3	1	2	2
5	4	1	1	1
6	4	1	1	1
7	4	1	2	2
8	4	1	2	2
9	5	1	1	1
10	5	1	1	1
11	5	1	2	2
12	5	1	2	2

TABLE 4-9
Predation by E. furcellata Nymphs
on Nymphs of Reduviolus roseipennis

Observation	E. furcellata Instar	E. furcellata No. of Nymphs	No. of R. roseipennis Nymphs	No. R. roseipennis Nymphs Killed on Day 1
1	3	1	1	1
2	3	1	1	1
3	3	1	2	2
4	3	1	2	2
5	4	1	1	1
6	4	1	1	1
7	4	1	2	2
8	4	1	2	2
9	5	1	1	1
10	5	1	1	1
11	5	1	2	2
12	5	1	2	2

TABLE 4-10
Predation by E. furcellata Nymphs
on Nymphs of Geocoris punctipes

Observation	E. furcellata Instar	E. furcellata No. of Nymphs	No. of G. punctipes Nymphs	No. G. punctipes Nymphs Killed on Day 1
1	3	1	1	1
2	3	1	1	1
3	3	1	2	2
4	3	1	2	2
5	4	1	1	1
6	4	1	1	1
7	4	1	2	2
8	4	1	2	2
9	5	1	1	1
10	5	1	1	1
11	5	1	2	2
12	5	1	2	2

TABLE 4-11
Predation by *P. maculiventris* Nymphs
on Nymphs of *Geocoris punctipes*

Observation	*P. maculiventris* Instar	No. of Nymphs	No. of *G. punctipes* Nymphs	No. *G. punctipes* Nymphs Killed on Day 1
1	3	1	1	1
2	3	1	1	1
3	3	1	2	2
4	3	1	2	2
5	4	1	1	1
6	4	1	1	1
7	4	1	2	2
8	4	1	2	2
9	5	1	1	1
10	5	1	1	1
11	5	1	2	2
12	5	1	2	2

The only parasitized egg mass encountered in the field was found in the Organic Gardens on the University of Florida campus. There, many kinds of vegetables are grown and no insecticide other than rotenone was used. About 1.2 hectares of alfalfa are grown immediately adjacent to the garden. On May 20, 1981, an adult T. basalis was observed to have just emerged from a N. viridula egg mass on the underside of a polebean leaf. On the same day, one E. furcellata and one P. maculiventris egg mass were placed on the underside of leaves adjacent to the leaf bearing the parasitized N. viridula egg mass. Ten days later both asopine egg masses were retrieved and found to be parasitized by T. basalis. Again, while suggestive, these data are insufficient to provide any sure indication of relative susceptibility of the asopine species to parasitization.

There is reason to suspect that action of T. basalis emerging from eggs of the usually more abundant plant feeding stinkbug seriously depresses the number of predacious species that would otherwise be present in soybean fields. Further studies are needed in order to quantify the positive role of T. basalis through its destruction of plant feeding stinkbugs and its negative role in destroying eggs of the predacious species that might otherwise be effective enemies of velvetbean caterpillar and other lepidopterous foliage feeders.

Egg masses of both asopine species were placed in a test tube (3 cm diameter, 20 cm long) with the T. basalis adults that had emerged about four hrs earlier. Within one minute, the asopine egg masses were attacked by T. basalis. Females of T. basalis flew to the egg masses and crowded together on the surface, using their antennae to tap the individual eggs, then turned their bodies around, finally inserting their ovipositors into the side of an egg. The ovipositor appeared to act as a drill, with 5 to 7 thrusts required to penetrate the egg chorion. Once the ovipositor was successfully inserted into the asopine egg, thrusting movements stopped and the ovipositor remained in the egg for about 5 to 10 seconds. After removing her ovipositor from the egg, the female T. basalis would immediately drag the tip of her abdomen across the egg surface several times in a figure 8 pattern. This evidently marked the egg, for no subsequent ovipositions were observed in such marked eggs.

The complete process took an average of 2 min. and 15 sec. under 30°C, 50 ± 10 RH in the laboratory. After about ten days, the next generation of T. basalis emerged from the exposed asopine egg masses. The percentage of parasitism was almost 100 in E. furcellata and P. maculiventris. On the basis of these data, there is no significant difference between the susceptibility of the two species to parasitism by T. basalis.

In no case were nymphal stages of either the big-eyed bugs or the damsel bugs observed to prey on the 1st instar of either asopine species when placed together in petri dishes. The tightly aggregated immobile 1st instar asopine nymphs were avoided by the big-eyed bugs and the damsel bugs placed in the same dish.

The 2nd instar nymphs of both asopine species were preyed on by the nymphal and adult stages of the damsel bug, R. roseipennis, and by the big-eyed bug, G. punctipes, while the 3rd, 4th, and 5th instar nymphs of the predacious stinkbugs were not attacked. To the contrary, the damsel and big-eyed bugs were occasionally killed by the larger stinkbug nymphs. Apart from the smaller size of the 2nd instars, they were unable to move as rapidly as the big-eyed bugs and the damsel bugs, and, as isolated individuals, were readily captured; however, no 2nd instars were observed to be attacked when they were members of an aggregation. Thus, the aggregation habit of the 1st and 2nd instars, and to a lesser degree that of later instars, may serve as a defense mechanism. The larger 3rd and later instars are able to move more rapidly than either the big-eyed or the damsel bugs and easily evade attacks or even turn and attack the would be attackers.

In this regard, the coloration of the large asopine nymphs appears to be significant. The larger nymphs exhibit rather striking color patterns involving red, orange, yellow, or black, often with a shiny metallic appearance.

Such color patterns are generally interpreted as serving to warn potential predators that the potential prey is able to defend itself or is otherwise undersirable. (Kettewell, 1961, 1965; Brower et al., 1960, 1965; Brower and Brower, 1962; Brower, 1971; Alcock, 1975). This evidence of difference in vulnerability of second instars and later stages of the predacious stinkbug points to the desirability of using 3rd instar nymphs in any release for control of velvetbean caterpillar in soybean fields.

No case was observed of an adult of either E. furcellata or P. maculiventris being attacked by any predators, although they are occasionally attacked by the tachinid parasitoid, Trichopoda pennipes (F.).

CHAPTER FIVE
MASS REARING OF THE ASOPINE BUGS EOCANTHECONA FURCELLATA (WOLFF) AND PODISUS MACULIVENTRIS (SAY) (HEMIPTERA: PENTATOMIDAE)

Introduction

The asopine bugs, P. maculiventris and E. furcellata, have been successfully laboratory reared on many factitious species (Mukerji and LeRoux, 1964; Chu and Chu, 1975; Winotai , * ; Pipatwatanakul ,**) . Mukerji and LeRoux (1964) reported the successful rearing of large numbers of P. maculiventris on wax moth larvae, G. mellonella. However, Chu and Chu (1975) failed in their mass rearing of E. furcellata using wax moth larvae as the factitious prey.

The main objective of our mass rearing of E. furcellata and P. maculiventris was to provide a source of bugs for comparative studies on development, fecundity, and longevity under different temperatures and photoperiods. A second objective was to provide a large number of bugs for use in field efficacy tests for suppression of soybean foliage pests, and perhaps establish this species permanently in the north

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**Personal communication: Kasetsart University, Bangkok, Thailand.

Florida soybean agroecosystem. Mass rearing of E. furcellata and P. maculiventris was conducted at the Insect Biological Control Laboratory of the University of Florida, Gainesville, since January 1980.

It is hoped that this study will contribute to the development of improved mass rearing technology for the two species, reduction of rearing costs, and production of more healthy bugs on a large scale for field release programs.

Literature Review

Both species have a high fecundity and are voracious general feeders on lepidopterous eggs and larvae, and many other insect pests (Stoner, 1930; Hayslip et al., 1953; Mukerji and LeRoux, 1964; Whitcomb et al., 1973; McPherson 1980 for P. maculiventris; Fletcher and Gibson, 1907; Jepson, 1918; Knowles, 1919; Corporaal, 1921; Sonan, 1922, 1924; Ballard, 1925; Pant, 1960; Vasantharaj, 1962; Rawat et al., 1972; Kapoor et al., 1973; Singh and Gangrade, 1975; Chu and Chu, 1975; Ghorpade, 1976; Rai, 1978; Chand and Prasad, 1978; Ung et al., 1979; Pipatwatanakul*, 1982; Winotai*, 1982 for E. furcellata). However, because he found E. furcellata feeding on a mulberry tree in Formosa, Maki (1918) mistakenly reported it as a pest.

*Personal communication.

P. maculiventris is a native North American insect which, according to Uhler (1876), Kirkaldy (1910), Woodworth (1913), Van Duzee (1914, 1917), and Blatchley (1926, 1934), is distributed from Quebec, west to Vancouver Island in Canada, south to Florida, and northern Mexico. E. furcellata, according to Cherian and Brachmacheri (1941), and Hsiao (1977), is present in the provinces of Szechwan, Kwang-tung, Kwangsi, and Taiwan of China; Coimbatore, Saidapet, Aduturai, Musirie, Bhiar, and Bengal of India; Burma, Sri Lanka, Thailand, Malaya, Borneo, Philippines, and Java.

The species furcellata was originally included in the genus Cimex (Wolff, 1802) and later transferred to Canthecona (Distant, 1902) and Cantheconidae (Sonan, 1924). Eocanthecona was erected by Hoffman in 1948.

Information on the life cycle of P. maculiventris has been provided by Forbush and Fernald (1896); Olsen (1910); Esselbaugh (1948); Mukerji and LeRoux (1964); Warren and Wallis (1971); Richman and Whitcomb (1978), while Chu and Chu (1975) and Winotai and Pipatwatanakul (personal communication) have given details of the life history of E. furcellata.

The laboratory rearing of P. maculiventris on various insect species has been documented by Morrill (1906), Olsen (1910), Whitmarsh (1916), Stoner (1930), Wilson (1933),

Howard and Landis (1936), Landis (1937), Couturier (1938), Esselbaugh (1948), Coppel and Jones (1962), Mukerji and LeRoux, (1964, 1969), Warren and Wallis (1971), Waddill and Shepard (1975a), Richman et al. (1978), and Wilkinson et al. (1979).

Chu and Chu (1975) and Pipatwatanakul (1980) (personal communication) have reported on the laboratory rearing of E. furcellata on various insect species.

Coppel and Jones (1962), studying P. maculiventris, reported that individual nymphs during their development were able to kill, but not necessarily consume, 11 to 15 larvae of the sawfly Diprion similis (Htg.), or an average of 13.4 larvae. Nymphs, if individually reared, can pass through their entire developmental period using only one D. similis for food. There was no apparent difference in weight of the teneral adults which had developed on a single prey species when compared with those which fed on multiple prey species during their nymphal period. If nymphs were not disturbed in feeding and if reared in small groups, they consumed an average of 2.8 larvae before becoming adult. If reared singly they consumed 4 larvae before reaching the adult stage. This apparent discrepancy in the number of larvae used for food may be due to desiccation of the sawfly larvae if not consumed by the attacking nymph. Morrill (1906) found that two 5th instar nymphs of P. maculiventris

consumed 26 larvae, while 2 adults consumed 220 larvae of the elm leaf beetle in 51 days.

Rai (1978), in India, reported that E. furcellata reared in the laboratory consumed 5-6 larvae of Melanitis leda ismene (Cramer) and Pelopidas mathias (F.) Kapoor et al. (1973), in India, found that nymphs of E. furcellata consumed 14-19 larvae of Spodoptera litura (F.) during their development and a pair of adults consumed 49-68 in 10-12 days. Chu and Chu (1975) reported that up to 4.6 3rd instar larvae of Pieris rapae (L.) and 7.7 3rd instar larvae of S. litura were consumed per day by adult E. furcellata when 30 larvae per jar of prey were placed in 20 cm by 10 cm jars. Pant (1960) found that the nymphs of E. furcellata consumed 7-8 larvae each during their development, and the adults consumed 4-8 per day and lived for 8-9 days.

Materials and Methods

Source of Stock

Eocanthecona furcellata was obtained from Dr. Banpot Napompeth, CIBC (Commonwealth Institute of Biological Control), National Biological Control Research Center, Bangkok, Thailand, in January 1980. They were received as 2nd and 3rd instar nymphs and unhatched eggs from a laboratory culture maintained at the Research Center. After being processed through the Quarantine Laboratory of the Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Gainesville, the immature stock was reared to adult and a culture was established.

A culture of Podisus maculiventris was established in August 1980 from adults collected from a soybean field on the Agronomy Farm of the University of Florida, Gainesville.

Rearing Methods

Adults of both species were separated and held in 1-quart glass fruit jars to which a lid was screwed in place over a disc of paper toweling that allowed for exchange of air. When wax moth larvae were used as prey it was necessary to replace the paper toweling with a 20-mesh metal screen to prevent the larvae from escaping. Two discs of paper toweling were placed in the bottom of the jar to absorb feces and excess moisture. When wax moth larvae were used to feed the bugs, these discs were omitted as the larvae would very often form cocoons in the paper toweling and escape the attention of the bugs. Three green beans were placed in each jar, primarily to maintain favorable humidity and to act as the source of moisture required by the bugs. Two strips of paper toweling (25 mm by 230 mm) were then placed in the jar to absorb excess moisture and to provide a resting surface for the bugs. Eggs were commonly laid on these strips, thus facilitating collection and labeling. The beans were changed as soon as they lost their turgor, and the bugs were then transferred to a clean jar with each change of beans, usually twice a week.

Initiation of Cultures

Eggs. Egg masses on labeled strips of paper toweling were held in petri dishes (1.2 cm deep by 9 cm diameter) with a section of green bean, the latter assuring the level of humidity required to insure maximum egg hatch.

First instar. After hatching, the 1st instars were also held in petri dishes as described above. After remaining for a day or two as an aggregation on the egg mass, they would commonly reaggregate on the bean. No prey was offered during this stage but the presence of a fresh green bean section was critical to the survival of the 1st instar.

Second and later instars. Once the 1st instars moulted to 2nd instars they were transferred to glass rearing jars. As they changed to 3rd and later instars their increased size and prey requirements made it necessary to subdivide the nymphal cohorts into additional jars so that not more than 25 last instars would be in any one jar.

Adults. One day after 5th instars transformed into adults, the adults were sexed and five pairs were placed together in a breeding jar prepared in the manner already described.

Egg harvesting. Egg masses were collected daily from the breeding jars. The masses were usually laid on the paper toweling strips, but when laid on the glass they were removed as a mass by means of a sharp knife blade that could

be slipped underneath the egg mass. These were then placed in a petri dish with a label indicating the date and jar of origin. The number of eggs was counted and recorded, as were the dates of those that hatched. Dead adults were removed daily and the date of death was recorded by sex.

Feeding. The brood cultures of both asopine species were maintained on a diet consisting of wax moth, cabbage looper, or velvetbean caterpillar larvae, depending on which species was most readily available. Wax moth larvae were reared by the author. Larvae of other species were generally provided by the Insect Cultures Section, United States Department of Agriculture, Insect Attractants and Basic Biology Laboratory, Gainesville.

Temperature, humidity, and photoperiod of rearing room. Both species were reared at 27 ± 1°C, 60 ± 10% RH with a photoperiod of 14L:10D.

Results and Discussion

The life cycles of E. furcellata and P. maculiventris are very similar (Table 5-1). In each species the duration of each suceeding instar is of somewhat longer duration than the preceding. The total developmental time from egg to adult is slightly longer for E. furcellata than for P. maculiventris. In E. furcellata this varies from 21 to 31 days with maximum emergence occurring between 25 and 26 days, while P. maculiventris adults emerged at between 20

TABLE 5-1

Days Duration of Each Stage of Eocanthecona furcellata and Podisus maculiventris

Species	Eggs Incubation	Days to Molt to Instar 1	2	3	4	5	Adult Longevity male	female
E. furcellata								
shortest duration	7	3	7	11	15	21	23	20
longest duration	10	4	9	15	21	31	47	42
(N)*	95	72	70	70	69	69	36	33
P. maculiventris								
shortest duration	4	3	7	11	15	20	48	30
longest duration	6	5	10	15	20	29	64	53
(N)*	63	50	47	46	46	45	23	22

*(N)=number of individuals

and 29 days with maximum emergence occurring between 24 and 25 days.

Female E. furcellata laid an average of 391.2 eggs, while those of P. maculiventris laid an average of 218 eggs, or about two-thirds of the number laid by E. furcellata. Eggs of E. furcellata hatched in about 8.5 days, and those of P. maculiventris hatched in about 5 days. Adult female E. furcellata lived for 20-42 days, male for 23-47 days. The adult life span of both sexes of P. maculiventris was considerably longer, with 30-53 days for females and 48-64 days for males (Table 5-1).

The percentages of eggs hatching for the two species were quite similar; 78.8% for E. furcellata and 76.0% for P. maculiventris (Table 5-2). However, an appreciably larger percentage of E. furcellata eggs were sterile (12.2%). The difference was compensated for by a larger percentage of P. maculiventris that, though fertile, failed to hatch, 15.9% as opposed to 8.9% for E. furcellata (Table 5-2).

Rate of Growth

While nymphal development of E. furcellata was, on the average, completed in 28 days and that of P. maculiventris in 26 days, the growth rate during this period was not uniform, being relatively slow during the first 17 days then accelerating rapidly as the nymphs transformed to 4th and 5th instars. The rate leveled off during the late 5th

TABLE 5-2

Fecundity and Fertility of Eocanthecona furcellata and Posisus maculiventris

No. of Replication	E. furcellata				P. maculiventris			
	No. Sterile	No. Failed to Hatch	No. Hatched	Total	No. Sterile	No. Failed to Hatch	No. Hatched	Total
1	52	31	324	407	22	34	166	222
2	80	38	335	453	13	41	160	214
3	65	37	333	435	24	20	174	218
4	30	14	205	249	10	49	168	219
5	41	50	317	408	17	40	179	236
6	36	28	348	412	16	33	172	221
7	27	5	403	435	36	25	171	232
8	42	26	216	284	28	58	164	250
9	56	69	267	392	6	22	158	186
10	49	50	338	437	4	26	151	181
Total	478	348	3086	3912	176	348	1655	2179
Mean	47.8	34.8	308.6	391.2	17.6	34.8	165.5	217.9
%	12.2	8.9	78.8		8.1	15.9	76.0	

instar. Table 5-3 shows the weight of eight replicated 10-specimen samples taken at seven-day intervals (except the last one) during the development period for both species. The nymphs of E. furcellata show a 3.6-fold increase in weight between 3 and 10 days, and a 2.5-fold increase between 10 and 17 days. Between 17 and 24 days, there was an approximate 6.5-fold increase, and a 2.6-fold increase between 24 and 26 days; while P. maculiventris nymphs showed only a 1.92-fold increase between 3 and 10 days, and a 3.9-fold increase between 10 and 17 days. Between 17 and 24 days the growth rate increased to 7.0-fold then declined to 2.6-fold between 24 and 26 days. In general, the growth rate of E. furcellata during nymphal development was somewhat more rapid than that of P. maculiventris (Figure 5-1).

Feeding Behavior

Mouth structure. In common with all asopine stink-bugs, E. furcellata and P. maculiventris differ from plant feeding pentatomids in having a short stout beak with the first segment freely exposed rather than lying in a groove on the underside of the head. The beak or rostrum, which consists of the labrum and enclosed mandibular and maxillary stylets, is admirably suited to pierce and hold prey. When not in use, it is carried close to the body between the coxae along the midventral line of the thorax. Body

TABLE 5-3
Growth Rate During the Nymphal Development of
Eocanthecona furcellata and Podisus maculiventris

No. Days Development	E. furcellata Total Weight*	No. of Bugs	Mean Weight	P. maculiventris Total Weight	No. of Bugs	Mean Weight
3	44.4	80	.56	40.8	80	.51
10	131.9	66	2.0	78.0	80	.98
17	305.5	61	5.01	230.9	61	3.8
24	1685.7	52	32.4	1517.6	57	26.6
26	4100.3	48	85.4	3814.8	56	68.1

*All weight are given in milligrams.

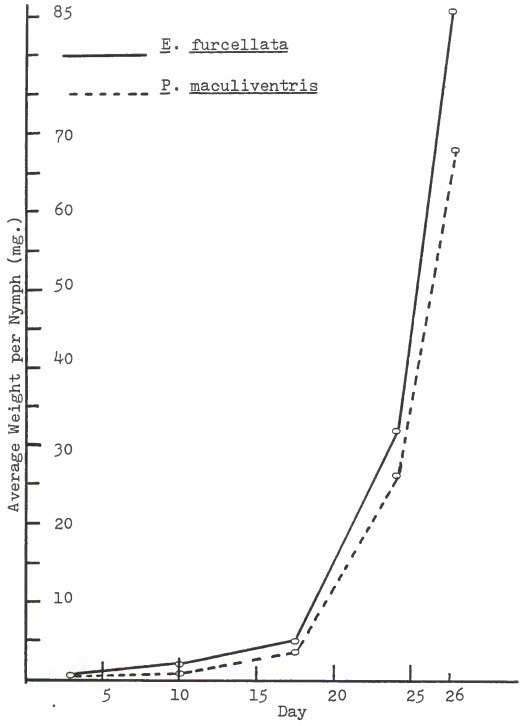

Figure 5-1. Growth Rate of E. furcellata and P. maculiventris during Nymphal Development

fluids of the prey are ingested through a food channel formed by the maxillary stylets. A second groove in the stylets forms a salivary duct. The stylets rather than the rostrum actually penetrate the integument of the prey, and it is through the stylets that enzymes are injected to immobilize the prey and predigest its tissues. The body fluids are then sucked from the prey through the food channel.

Stages exhibiting predacious habits. Like all asopine species, E. furcellata and P. maculiventris are predacious in all stages except the lst instar. First instars are not known to feed, but can be seen probing plant tissue presumably for water, which if not available results in immediate death. This is particularly true under conditions of low humidity.

Pre-attack behavior. In the case of both species, once a bug perceives the presence of a potential prey it extends its rostrum downward and forward. As the rostrum is moved forward, it is usually stroked or rubbed by the tibiae which are also frequently used to clean the antennae.

Prey capture. Having found a potential victim presumably by sight, though some kairomonal action may also be involved, the bug of either species first contacts the prey with its antennae, usually tapping it gently. The rostrum is then extended horizontally in front of the head

with the antennae held more or less parallel and moving rapidly up and down. As the tip of the rostrum touches the integument of the prey, the stylets penetrate and at the same time or possibly before, a small amount of fluid is emitted from the tip of the rostrum. Initially a clear watery substance, this fluid hardens almost on contact, thus cementing the tip of the rostrum to the prey.

Such a mechanism has obvious advantages, the foremost being that of holding the prey without excessively stressing the stylets through which the bug must feed. At cessation of feeding, the "cement" is softened, presumably a result of some enzyme action, and, as the rostrum is withdrawn, the adhesive tends to be pulled out to form a microscopic nipple and rehardens in this form.

Prey defense. The bugs are not invariably successful when they find and attempt to capture prey. The bug's strategy relies on stealth and it tries to contact and cement its rostrum to the prey's integument probably before it inserts its stylets into the prey's body. Following insertion of the stylets, the victim is usually paralyzed within a few seconds, presumably as the result of some toxic or analgesic substance in the bugs' saliva. However, if the prey is alerted, it will often take evasive action and in the case of some species, actually defend itself. The various phenomena associated with prey defense against

P. maculiventris have been discussed by Kershaw and Kirkaldy (1909), McDermott (1911) and Baker (1927). The behavior of prey in the presence of E. furcellata does not differ from that aroused by P. maculiventris.

Actual feeding. When observed closely, particularly in the case of prey with a semitransparent integument, the stylets once through the integument thrust and whip about the interior of the body and occasionally exit briefly through the integument at a point removed from that of entry. This would seem to function as a means of breaking down the prey's body contents into ingestible form. Presumably, this is brought about by the piercing, whipping action of the stylets as well as by an associated release of a digestive enzyme.

Termination of feeding. If feeding terminates normally, the stylets are first withdrawn, then the rostrum detaches leaving a small spot of hardened adhesive at the point of earlier attachment. If disturbed and forced to disengage hurriedly from the prey, the adhesive will sometimes adhere to the tip of the rostrum as a yellowish semitransparent flake. In this case, it is quickly removed by grooming action of the forelegs. Even without the adhesive dot, the site of a feeding puncture usually can be detected as a small, slightly discolored spot.

Aggregation Behavior

Aggregation behavior is exhibited during the quiescent period prior to, during, and subsequent to molting. Nymphs commonly cluster on the walls of glass jars for about 6 hrs or more with their heads pointing downward in position for molting. When aggregated. the combined odor released from the abdominal glands of each nymph is believed to provide protection from attack by predators (Waterhouse et al., 1961; Remold 1963; Ishiwatari, 1974). The combined odor and aposematic effect of a highly visible aggregation of nymphs would seem likely to protect a molting individual. The asynchrony of molting observed in the case of both species would be a special advantage in preventing attacks by predators. Aggregation does appear to contribute to more rapid molting and reduction in molting mortality. Nymphs developed a few days faster and grew larger when 25 individuals were reared together compared to nymphs reared in isolation. Also, 25 nymphs reared as a group molted faster than nymphs reared in isolation and appeared to feed more aggressively. Mortality of the 25 nymphs reared as a group was 2% for E. furcellata, and 3.2% for P. maculiventris, while the mortality of nymphs reared alone was as high as 30% for E. furcellata and 40% for P. maculiventris (Tables 5-4-7).

Omitting the 1st instar which does not feed, both species can successfully attack prey many times larger than

TABLE 5-4

Number of Eocanthecona furcellata Completing Nymphal Development when 25 Nymphs were Reared Together as a Group

No. of Replications	Beginning No. (1st Instar)	Ending No. (Adult)	Sex	
			Male	Female
1	25	25	14	11
2	25	24*	12	12
3	25	25	15	10
4	25	24*	8	16
5	25	25	16	9
6	25	25	17	8
7	25	25	15	10
8	25	22*	12	10
9	25	25	7	18
10	25	25	9	16
Total	250	245 (98.0%)	125	120
			1.04:1	

*Deaths in 2nd instar.

TABLE 5-5
Number of Podisus maculiventris Completing Nymphal Development When 25 Nymphs were Reared Together as a Group

No. of Replications	Beginning No. (1st Instar)	Ending No. (Adult)	Sex	
			Male	Female
1	25	23*	16	7
2	25	25	10	15
3	25	25	7	18
4	25	22*	14	8
5	25	25	13	12
6	25	24*	15	9
7	25	25	9	16
8	25	25	14	11
9	25	25	12	13
10	25	23**	17	6
Total	250	242 (96.8%)	127	115
			1.10:1	

*Deaths in 2nd instar
**Deaths in 5th instar

TABLE 5-6
Number of Eocanthecona furcellata Completing Nymphal Development when Reared in Isolation

No. of Replications	Beginning No. (1st Instar)	Ending No. (Adult)	Sex	
			Male	Female
1	1	1		1
2	1	1		1
3	1	*		
4	1	1	1	
5	1	1		1
6	1	1	1	
7	1	**		
8	1	1	1	
9	1	**		
10	1	1	1	
Total	10	7 (70%)	4 1.33:1	3

*Death in 2nd instar
**Deaths in 3rd instar

TABLE 5-7
Number of Podisus maculiventris Completing Nymphal Development when Reared in Isolation

No. of Replication	Beginning No. (1st Instar)	Ending No. (Adult)	Sex Male	Female
1	1	*		
2	1	*		
3	1	*		
4	1	1	1	
5	1	**		
6	1	1	1	
7	1	1		1
8	1	1		1
9	1	1	1	1
10	1	1		
Total	10	6 (60%)	3	3
			1:1	

*Deaths in 2nd instar
**Deaths in 3rd instar

the bugs, irrespective of stage of development. However, the time spent to capture prey is much shorter if the prey size is small. If the prey is too large to be completely consumed, it will not be fed on later as neither species will feed on cadavers. If forced by starvation to feed on already dead prey, nymphs of both species usually died. However, under field conditions inability to fully consume prey should not result in any adverse effects and might be advantageous since the prey would in any event be dead and no longer destructive to plants.

Results show that both asopine species developed satisfactorily when wax moth larvae were provided as a factitious prey for all nymphal instars (except the 1st) and adults. Similar results were reported for P. maculiventris by Mukerji and LeRoux (1964). However, Chu and Chu (1975), who studied feeding habits of E. furcellata in Taiwan, indicated that wax moth larvae were unsuitable prey for asopine bugs. They attributed this to the wax moth larva's thick integument and agility that made capture difficult. They concluded that no nymphs could develop from 2nd instar to 3rd instar when wax moth larvae were provided as prey. The integument of wax moth larvae may be thicker than cabbage looper's and they may be more active than other lepidopterous larvae, but in our present observations, the 2nd instars of both species were able to capture wax moth larvae with no difficulty.

Most often, wax moth larvae constructed their cocoons on the screen lid of a rearing jar. Once the cocoon was constructed, the larvae stayed quietly in their cocoons. Such behavior led to their being easily captured by both asopine species. The place where the wax moth larvae tended to make cocoons was usually the place where both asopine species tended to stay. Such behavior offered very important advantages. First, the bugs saved much time otherwise needed to find the wax moth larvae. Second, because wax moth larvae were quiescent in their cocoons, capture was more easily accomplished. Third, the wax moth larvae were not contaminated by the feces on the bottom of the jars; this constitutes perhaps the greatest advantage over other kinds of lepidopterous larvae that tended to remain on the bottoms of rearing containers and were more contaminated by feces. Fourth, wax moth larvae do not feed on green beans or other plants and thus do not destroy the plant material needed by the bugs as a source of water or humidity. Fifth, because of their smaller size, the wax moth larvae are more likely to be completely consumed. Sixth, wax moth larvae can be produced more easily and at lower cost. Therefore, this author believes that wax moth larvae are not only a suitable prey, but are also superior for feeding both asopine bugs.

Temperature and relative humidity are other important factors. In general, both species, when reared at high

temperatures (over 30°C) and high humidity (over 70%RH) were adversely affected as indicated by a high mortality rate. Adverse combinations of temperature and relative humidity not only retard growth and reproduction but directly contribute to mortality during molting. This is particularly true when 5th instar nymphs attempt to molt to adults. During the critical process of molting, many nymphs may be unable to extricate themselves from the skin they are attempting to shed; hence they soon die in the act of ecdysis.

Photoperiod is another important factor in regulating the development cycle in both species. When they are reared under controlled and similar conditions with respect to temperature and humidity, both species develop at a much faster rate in a long-day photoperiod than in a short-day photoperiod. More detailed results on the effects of temperature and photoperiod are reported in Chapter Two.

Efficient handling and feeding methods are of paramount importance in rearing large numbers of asopine bugs. Without an efficient handling method, it is easy to kill nymphs contained in rearing jars and more time must be devoted to their care. Without an efficient feeding method, the nymphal development is not uniform and mortality may increase due to cannibalism. If insufficient food is available, fecundity is reduced. However, when too many

prey are provided the crawling prey may kill molting nymphs or occasionally eat the nymphs. Wax moth and cabbage looper larvae were observed to eat nymphs of both species during molting.

To avoid cannibalism, the age of asopine nymphs in the same jar should be as uniform as possible; otherwise cannibalism often occurred during molting. To obtain uniformity of age, nymphs from the same egg mass should be reared in the same rearing jar and fed an excess of prey.

Nymphs and adults preferred to feed on live prey, but the amount consumed at each feeding is limited, and if the prey are too large to be entirely consumed during one feeding they will seldom be fed on at a later time. Dead prey should be removed from the jar as the decaying remains create highly unfavorable conditions for the nymphs and adults, often resulting in death or greatly reduced vigor. The relation of prey size to condition of cadavers may explain why the mortality of E. furcellata was much higher when fed armyworm than when fed the smaller and less active stem borer and European corn borer larvae (Chu and Chu, 1975). While less active prey are usually captured on first contact, more active prey often escape but eventually succumb to subsequent attacks. The bugs are persistent and often appear to cooperate in capturing and subduing an active prey.

Nymphs of both species in all stages stop feeding and remain quiescent for a few hours to 1-2 days before molting. During this period they may be eaten by the prey if it has no access to its normal food.

Fresh green beans were used as a source of water and as a means of maintaining a favorable level of humidity in the jars. However, there were several disadvantages associated with their use. First, because they were purchased from the market, there was always the danger of contamination with insecticides or other toxicants that might cause the death of the bugs. Such a problem was suspected on two occasions during the two year period of this study. Second, green beans are often quite expensive. In the case of cabbage looper and certain other plant feeding species, the beans would be eaten and the bugs deprived of a water source. Also, the jars were fouled by feces causing adverse conditions for the bugs. To avoid the disadvantages of beans, some researchers substitute a moist cotton ball placed on the top of the screened jar lid. This method was used by Mukerji and LeRoux (1964) in their study of P. maculiventris, and by Waddill and Shepard (1974) with Stiretrus anchorage (F.)

E. furcellata laid about 1.79 times (391 versus 218) more eggs than P. maculiventris (Table 5-7). No direct reduction of fecundity was detected in either species when

fed exclusively on a diet of wax moth larvae for all nymphal (except 1st) instars and adults. Fecundity of the asopine bugs is correlated with adult female body size (Evans, 1982) and with crowding (i.e., density of adults per jar) (Mukerji and LeRoux, 1964). These authors also found that under laboratory conditions female body size was in turn correlated with the quantity of prey consumed during nymphal development. In this study, this factor was avoided by providing an excess of prey in the rearing jars at all times.

Oviposition of the asopine bugs is to some extent density-dependent (i.e., increasing populations in the rearing jars inhibit egg production). The largest number of eggs per female could be obtained by placing only one pair of adults in each jar. However, greatest yield of eggs in terms of labor and material was obtained when five pairs were housed in each jar. Using this system fecundity per female was 391 for E. furcellata and 218 for P. maculiventris. Approximately 500 1st instar nymphs were produced daily from 16 breeding jars for each asopine species. Disease was not a serious problem during this rearing program. Two cases of sudden death of young nymphs were attributed to contamination of green beans by an unknown toxicant. No symptoms of disease were noted in either of these instances.

The rearing method reported here provided a sustained production of adquate numbers of nymphs for the field and

laboratory research with minimal input of manpower and modest laboratory facilities.

CHAPTER SIX
MASS REARING OF PREY, THE WAX MOTH, *GALLERIA MELLONELLA* L. (LEPIDOPTERA: PYRALIDAE)

Introduction

As indicated in the first chapter, the object of this research was to compare the life histories and to predict the performance of a stinkbug, *Eocanthecona furcellata* (Wolff) from southeastern Asia, and the common North American species, *Podisus maculiventris* (Say). In order to provide the number of eggs, nymphs of various stages, and adults to carry out the required experimental studies, it was necessary to develop a method of rearing predetermined numbers, ranging from the small numbers needed for laboratory studies to 5000 needed for a large field experiment designed to compare the efficacy of the two species.

A further consideration in development of a mass rearing method was the prospect that the field experiment would yield sufficiently promising results to warrant consideration of use of one or both of the predacious species of stinkbugs as a tactic for management of velvetbean caterpillars in soybean fields. In this event, it would be important to produce millions of the predacious bugs at a cost that could be competitive with other possible tactics currently available for control of this pest.

As a secondary objective of this research, colonization of E. furcellata was to be undertaken in the hope that the species would become a permanent member of the North American beneficial insect fauna. To carry out field colonization releases with a reasonable prospect of success, large numbers would be required in addition to those needed for the comparative life histories and field efficacy studies. For these reasons, special attention was given to the problems of mass producing the two species of stinkbugs.

Since both species are highly polyphagous there was a wide choice of possible prey on which they might be reared. The question was one of selecting a factitious species that would satisfy the nutritional requirements of the predacious bugs and could be reared at a minimum cost of material and labor. After preliminary tests involving the cabbage looper, Trichoplusia ni (Hubner), and the velvetbean caterpillar, A. gemmatalis, the greater wax moth (hereafter referred to as wax moth), G. mellonella, was chosen. The wax moth offered several advantages over the other species. It is much more tolerant of wide ranges of temperatures and humidity and is much less susceptible to disease than the other species. Several diets were also available that were less costly and easier to handle than those required to rear the normally leaf-feeding species.

Literature Review

Wax moth larvae are a common pest of honeybee combs. Utilization of wax moth larvae as fish bait, as the subjects for research in the study of insect physiology, for feeding to predatory insects, as a factitious host for rearing parasitoid insects, and as the host for producing microbial agents are well known. Techniques for rearing this species have been described by Silhacek (1966), Marston et al., (1975), Jaycox (1979), and Nielson (1980) (personal communication).

The wax moth can be found in a variety of situations but usually in association with honeybee combs. They can be reared in a container filled with old honey comb, but it it difficult to obtain enough comb to produce large numbers of larvae and the cost of purchase is prohibitive. Also, it is difficult to produce successive batches of larvae in predetermined numbers.

Jaycox (1979), who studied the wax moth in Illinois, successfully reared larvae on three different diets. The formulae for his diets are shown in Table 6-1. He reported that the female lays as many as 1600 eggs in a lifetime, preferring to place them in cracks or beneath objects. He pointed out that about 1000 eggs are sufficient to stock a 1-gallon jar containing about 0.68 kg of diet with expectation of harvesting about 500 mature larvae.

TABLE 6-1
Formulae for Jaycox's 1979 Diets

Diet No.	Ingredients	Amount by Volume	Amount by Weight (gm)
1	granular dog meal	7	
	water	1	
	honey	2	
2	baby cereal	*	
	glycerin	2	
	water	1	
3	wheat flour		162
	cornmeal		162
	bran		216
	wheat		60
	glycerin		260
	water		140

*Mixed baby cereal with the liquid mixture to the point of being able to mold it into a ball that crumbles easily.

The eggs hatch in about 4 days; the larvae feed and grow for at least 29 days, then pupate and emerge as adults after about 7 days.

Methods and Materials

Establishment of Wax Moth Culture

The initial stock of wax moth was obtained from two sources. The first was old honeybee comb discovered in the author's apiary. Larvae in these comb were allowed to pupate and eggs were obtained from the adults. The second source consisted of eggs obtained from R. A. Nielson, USDA, Apiculture Research Laboratory, Baton Rouge, LA. After hatching, larvae from both sources were reared on the diet described by Nielson (personal communication). Newly emerged adults were placed in a refrigerator at 5°C and chilled for 5 minutes in order to facilitate handling. One hundred adult moths were placed in 33 x 25 x 11 cm plastic containers. The plastic containers were then placed in a darkened cabinet at 30 ± 1°C and approximately 60% RH. Food was provided in the form of a solution consisting of 1 gm of honey in 10 ml of water. This was then absorbed by a piece of cotton placed in an open petri dish enclosed in the plastic rearing containers.

Harvesting Eggs

When housed in the plastic containers, the females preferred to lay their eggs in the narrow space between

the flange of the lid and the inner surface of the side of the container. The eggs were usually attached to the lid rim and could easily be removed in layered strips about 6-8 cm long. Eggs were harvested at the same time daily, then washed for 5 minutes in fresh water, placed in a 10% bleach solution for 2 minutes, and transferred to fresh water for 2 minutes. They were then collected by means of an eye dropper and dispensed on sterile paper towels. After the eggs were completely dry, 10 mg of dry eggs were placed in a 3-dram vial which was then filled with larval diet and placed in the bottom of a quart Mason jar to which 335 mg of diet was then added.

Diet Preparation

In order to compare costs and quality of reared wax moth larvae, four different diets were tested. Diets 1, 2 and 3 all included sugar, water, glycerin, and vitamins, but differed in their source of protein. This was provided by one of the following ingredients: Gerber's^{R} Mixed Baby Cereal, earthworm and cricket feed, or soybean flour. The formula for each of the diets provides about 1.5 kg of diet. For Diets 1, 2 and 3:

Ingredients	Quantity
1. water	110 ml
2. sugar	224 gm
3. glycerin	350 ml
4. vitamins	1 ml

5. Diet 1: Gerber's® baby cereal 896 gm
   Diet 2: earthworm and cricket feed* 896 gm
   Diet 3: soybean flour mixed with earthworm and cricket feed (1:1) 896 gm

Combine ingredients 1 and 2 at room temperature and heat to boiling. Next add ingredient 3 and again heat to boiling. Cook for about 5 minutes using a pressure cooker at 15 lb pressure. Allow to cool to room temperature, add ingredient 4 and mix thoroughly. Add ingredient 5 and mix thoroughly.

For Diet 4:

Ingredient	Quantity
1. honey	650 ml
2. vitamins	1 ml
3. soybean flour mixed with earthworm and cricket feed (1:1)	896 gm

Combine ingredients 1 and 2 at room temperature, add ingredient 3 and mix thoroughly.

*Earthworm and cricket feed ingredients: wheat middlings, soybean mill feed, corn, dehydrate alfalfa meal, molasses, vitamin A palmitate, d-activated animal sterol (source of vitamin D_3), vitamin E supplement, menadione sodium bisulfite (source of vitamin K activity), niacin, riboflavin, vitamin B_{12} supplement, folic acid, choline chloride, calcium pentothenate, ethoxyquin (a preservative), mangous oxide, zinc oxide, iron carbonate, copper oxide, potassium idodide, cobalt carbonate, iron sulfate, calcium carbonate (Manufactured by Carnation Co., Los Angeles, CA).

Rearing Container

Into each quart Mason jar were placed 335 gm of diet. The jars were then placed in a dark cabinet. The lid rings of the jar were each fitted first with a disc of 40-mesh copper screen, then a disc of paper towel, and sealed securely to the jar top. The paper towel served to prevent the escape of very small larvae. Next, 10 mg of eggs were placed in 3-dram vial. The vial was then filled with diet and buried under about 8 cm of diet in the jar.

The number of days from eggs to hatching, duration of larval development, date of prepupal formation and date of transformation to pupa, date of adult emergence, date of mating, duration of oviposition, weight of eggs laid, and longevity were recorded. Records were also kept on the number of larvae reared from each jar and 15 mature larvae were randomly selected for determination of mean larvae weight. Five jars were regularly selected at random from those set up for tests and used to provide adults for the next generation.

Harvesting Larvae

Most mature larvae climb to the lid in search of a pupation site. When a small number of larvae were needed these were readily obtained by picking the larvae from the inner lid surface where they tend to form their cocoons.

However, for harvesting large numbers of larvae a wire screen sieve was used. Two days before the larvae would normally begin to climb to the jar lid., i.e., about 25 days after hatching, all diet should be removed from the jar and placed on a 6 x 6 mm mesh screen. The diet then should be worked gently through the screen. The larvae remain on the screen and may then be collected.

Results and Discussion

Quantity of Eggs Laid

Females laid an average of 1057.5 eggs and had an average longevity of 12.9 days (Table 6-2).

Rearing Conditions

For optimum production of larvae, the optimum temperature was 30 ± 1°C with 60 ± 10% RH. If the humidity exceeded 70% RH serious contamination occurred in the medium, followed by overheating and death of the larvae.

The optimum temperature and humidity for adult moths were the same as for larvae. Excessive humidity resulting in condensation of water on the inside walls of the containers caused immediate death. However, when honey with water (about 10 ml total) was used for adult feeding, no excessive humidity was encountered.

Oviposition Behavior

Most eggs were deposited on the edge of the plastic oviposition container. The females preferred to find a

TABLE 6-2
Fecundity and Longevity of Wax Moth,
Galleria mellonella

Female	Number of Eggs	Longevity (days)
1	593	14
2	988	12
3	1062	12
4	1039	23
5	1139	14
6	934	13
7	1096	15
8	1183	14
9	1085	12
10	1164	12
11	1097	13
12	1188	14
13	1042	12
14	1142	13
15	1037	12
16	1077	12
$\bar{x}$	1057.5	12.9

crevice-like space between the lid flange and the rim of the container for oviposition. The width of the crevice selected ranged from 1.0 to 1.5 mm. Eggs were laid one by one after the ovipositor was inserted into the crevice. The first egg was deposited near the edge of this crevice and the second was placed adjacient to the first but deeper. Subsequent eggs were laid in a line until the ovipositor was fully extended. The ovipositor would be retracted and an additional row of eggs laid against the first with the female moving her body forward as necessary to accommodate continued oviposition.

Amount of Larvae Harvested

Ten mg of wax moth eggs (approximately 370 eggs) were introduced into each jar. The egg stage lasted a mean of 6.4 days. The mean duration of larval development was 28.5 days, of the pupal stage 9.1 days, and adult longevity was 12.5 days (Table 6-3). In other words, about 35 days after egg deposition, the maximum quantity of larvae of wax moth may be harvested from each rearing jar. However, for the younger stages of the predatory bugs, i.e., 2nd and 3rd instars, small-sized wax moth larvae are needed and should be harvested about 15 days after hatching.

The mean number of larvae reared from each jar were 350, 354;327, and 359 for Diets 1, 2, 3, and 4, respectively (Table 6-4). The mean weight in mg of individual larvae was 272.4, 277.7, 268.4, 294.6, pupa was 87.6, 87.3,

TABLE 6-3
Duration of Each *Galleria mellonella* Stage (Days)

Diet No.	Jar No.	Egg	Larvae	Pupa	Adult
1	1	7	28	9	14
	2	6	30	8	12
	3	7	29	9	12
	4	6	29	9	13
$\bar{x}$		6.5	29.0	8.8	12.8
2	1	6	29	8	12
	2	5	29	10	12
	3	6	28	9	13
	4	6	28	9	12
$\bar{x}$		5.8	28.5	9.0	12.3
3	1	6	29	11	12
	2	7	28	9	13
	3	7	28	9	12
	4	7	28	9	13
$\bar{x}$		6.8	28.3	9.5	12.5
4	1	7	29	10	12
	2	7	28	9	12
	3	6	28	9	13
	4	7	28	9	12
$\bar{x}$		6.8	28.3	9.3	12.5
Overall Mean		6.4	28.5	9.1	12.5

TABLE 6-4
Yield of Galleria mellonella Larvae
From Rearing Jars on Diets 1, 2, 3, and 4

Replications	No. of Larvae Harvested			
	Diet 1	Diet 2	Diet 3	Diet 4
1	347	357	310	356
2	355	349	296	361
3	340	354	350	354
4	346	360	345	351
5	353	348	305	364
6	361	358	357	370
Total	2102	2126	1963	2156
Mean	350	354	327	359

89.2, 90.5 (Table 6-5) on Diets 1, 2, 3, and 4, respectively (Table 6-6). Approximately 350 mature larvae were harvested from each rearing jar with remarkable consistency.

Cost of Diet

The cost of materials for producing these quantities of larvae from each glass rearing jar was $0.42, 0.21, 0.31, and 0.36 for Diet 1, 2, 3, and 4, respectively (Table 6-7). Although Diet 2 was the least costly in terms of material, Diet 4 was more convenient to prepare since it did not need to be cooked, which reduced the time needed for preparation.. Also, honey is readily obtained from any grocery store, while glycerin must be ordered from a drug store or other supplier.

Conclusion

Diets 1, 3, and 4 are modified versions of earlier diets developed by Jaycox, (1979) and Nielson, (personal communication). Diet 2, containing sugar, glycerin, vitamins, and earthworm and cricket feed, proved equal or superior. No apparent reduction in viability was detected among the tested diets. Based on time to complete a generation and the weight of the larvae, differences among the four diets were not significant at the 5% level (Table 6-8).

The cost of ingredients and labor required to prepare the diet, collect and dispense eggs, and to harvest larvae,

TABLE 6-5
Mean Weight of *Galleria mellonella* Pupa
on Four Different Diets

Replications	Mean Weight of Pupa (mg)*			
	Diet 1	Diet 2	Diet 3	Diet 4
1	91.2	87.7	89.1	91.9
2	86.7	85.8	90.0	89.9
3	88.7	87.9	89.1	90.9
4	87.7	88.5	89.1	90.0
5	85.9	86.5	89.0	90.3
6	85.7	87.4	89.1	90.3
Total	525.9	523.8	535.4	543.2
Mean	87.6	87.3	89.2	90.5

*Mean weight counted from 15 pupa/replication

TABLE 6-6
Mean Weight of Galleria mellonella Larvae on Four Different Diets

Replications	Weight of Larvae (mg) Diet 1	Diet 2	Diet 3	Diet 4
1	354.4	276.6	305.5	300.6
2	224.5	259.7	331.7	300.0
3	254.8	265.7	242.8	335.0
4	278.8	249.8	246.6	257.0
5	267.1	311.3	240.6	300.0
6	254.6	303.2	242.9	275.6
Total	1634.2	1666.4	1610.2	1767.6
Mean	272.4	277.7	268.4	294.6
SD[a]	44.1	24.6	36.4	23.6
SE[b]	18.0	10.6	14.9	9.6

[a]SD=standard deviation
[b]SE=standard error

TABLE 6-7
Cost of Four Different Diets for Rearing Galleria mellonella

Diet No.	Materials	Quantity	Cost
1	sugar	224 gm	$0.13
	glycerin	350 ml	1.53
	baby cereal	896 gm	2.04
	vitamin	1 ml	0.10
	Total for 9 jars		$3.80
	Cost per jar		0.42
2	sugar	224 gm	$0.13
	glycerin	350 ml	1.53
	earthworm & cricket feed	896 gm	0.12
	vitamin	1 ml	0.10
	Total for 9 jars		$1.88
	Cost per jar		0.21
3	sugar	224 gm	$0.13
	glycerin	250 ml	1.53
	soybean flour mixed with earthworm & cricket feed (1:1)	896 gm	1.00
	vitamin	1 ml	0.10
	Total for 9 jars		$2.76
	Cost per jar		0.31
4	honey	650 ml	$2.14
	soybean flour mixed with earthworm & cricket feed (1:1)	896 gm	1.00
	vitamin	1 ml	0.10
	Total for 9 jars		$3.24
	Cost per jar		0.36

TABLE 6-8
T Test for Significance of Difference in Mean Weight of Larvae Harvested from Different Diets

Comparison Item	t Value
Diet 1:Diet 2	-0.21 NS
Diet 1:Diet 3	0.21 NS
Diet 1:Diet 4	-1.04 NS
Diet 2:Diet 3	0.52 NS
Diet 2:Diet 4	-1.21 NS
Diet 3:Diet 4	-1.48 NS

$t_{0.05,\ 5}=2.57$

as well as the quality of the harvested larvae, are major factors to be considered in mass rearing prey.

In order to obtain uniform sized moth larvae, the difference in the age of wax moth eggs should not exceed one day. In other words, eggs of the wax moth should be harvested at the same time daily and placed immediately in rearing jars in order to assure uniform ages of larvae produced in each jar.

Ten mg of wax moth eggs are the optimum quantity of eggs for each rearing jar. If the amount of eggs per rearing jar exceeds 10 mg, no problem will be encountered during the first 15 days after hatching; however, after 15 days the rapidly growing larvae in the over-populated jars will result in excessive production of metabolic heat and water, causing the death of the larvae. The eggs should also be placed in 3-dram vials filled with diet before being embedded in the diet contained in the rearing jar. This prevents excessive wandering of newly hatched larvae and escapes from the jar. If this procedure is not followed the jar yield cannot be accurately predicted.

The optimum amount of diet per jar was found to be 335 gm. In excess of this amount the diet was not fully utilized and could not be reused because of fungus problems and the inability to predict the number of larvae produced.

The protein content in diet is an important factor in rearing wax moth larvae. As a general rule, larval

development is positively correlated with percent of protein content. In addition to providing a source of carbohydrate, the function of honey or glycerin with sugar seems to be that of maintaining a level of moisture sufficiently high to allow development of larvae and at the same time low enough to inhibit growth of fungi. Fungus problems were seldom encountered with any of the four diets as all contained less than 20% water. Under such conditions it was not necessary to add any antiobiotic drugs to the diet. This avoids additional diet cost and elminates a possibly adverse effect on larval development. Also, it is not necessary to cook baby cereal, soybean flour, or earthworm and cricket feed. This not only saves time but eliminates an additional labor cost. Diet 2 proved to be least costly, yielding 354 larvae, each weighing about 278 mg, at a cost of $0.21 for ingredients.

Diet 2, in which the basic ingredient is earthworm and cricket feed, has the advantage of remaining finely granulate, while baby cereal and soybean flour tended to become sticky or gummy. The granulate character of Diet 2 makes it possible to harvest large numbers of larvae through the use of the wire screen sieve method which greatly reduces labor costs.

Diet 1, 2,and 3 include sugar, glycerin, and water which must be cooked and thus requires more time and labor

than Diet 4. In addition to eliminating the cooking process, the honey component of Diet 4 can be purchased at any grocery store.

For harvesting small numbers of wax moth larvae, the time and labor cost is of little consequence. However, for harvesting large numbers, Diet 2 required the least time and labor. If the time and labor spent on the harvesting process is estimated in terms of time units, approximately 2, 1, 3, and 3 units are required for Diets 1, 2, 3, and 4, respectively (one time unit is estimated to be, for this research, approximately 4 hours).

Approximately eight mature wax moth larvae were needed to rear one asopine bug of either species, E. furcellata or P. maculiventris, from egg to adult. Thus, using Diet 2 it should be possible to rear 100 asopine bugs through to the adult stage at a cost of $0.48 for host larvae. The time required to feed and otherwise attend the developing bugs is an additional cost of approximately an equal amount. In an augmentation program utilizing 2nd or even 3rd instars, the cost per hundred would be reduced by at least one-tenth or approximately $0.96 per 1000 nymphs. With sustained large scale production, it would be possible to incorporate further refinements in techniques of rearing prey larvae and predatory bugs that would greatly increase efficiency of operation and substantially reduce costs.

CHAPTER SEVEN
CONCLUSIONS

As expected from their geographic distribution the experimental studies showed P. maculiventris to perform better than E. furcellata at temperatures of 18.3°C and 23.9°C. However, the latter was superior at 29.4°C. This was most pronounced under short day conditions where the developmental time of E. furcellata was greatly prolonged, nymphal mortality increased, and fecundity reduced to a much greater degree than was true for P. maculiventris. An interaction between temperature and day length was apparent with both species showing prolonged development under short light at the middle and lowest temperature but little change at the highest temperature (Table 2-36).

The greater intensity of the interacting effects of light and temperature on E. furcellata (as also indicated in rates of generation increase (Table 2-39)) is especially interesting. With its distributional range in southeast Asia falling entirely below 30° latitude, E. furcellata has never experienced the wide seasonal changes in day length prevailing in much of the north American continent inhabited by P. maculiventris. It would appear from these results that E. furcellata does utilize photoperiod as a cue to regulate its annual

population cycles, but because of the small seasonal change in day length characteristic of latitudes below 30° it must be more sensative to change in day length than P. maculiventris. This is indicated by changes in the number of days required to complete a generation at 18.3 °C, 23.9°C and 29.4°C under 16 hours light (Table 2-36). E. furcellata was found to require 54% more time at 18.3°C than that required at 29.4°C. For P. maculiventris the comparable time increase was 50%. Under 8 hours light (Table 2-36) neither species showed a striking change at 29.4°C, though for E. furcellata, time required was actually shortened by about 4 days while that for P. maculiventris was lengthened by 1.5 days. The effect of light becomes very evident at the lower temperatures where at 18.3°C. P. maculiventris required 94% more time that at 29.4°C and the equivalent figure for E. furcellata was 145%.

It is of interest that short light decreased longevity of male P. maculiventris while prolonging that of the female (Tables 2-32 and 2-34). This might be explained as an adaptation to prolonged winter diapause which is characteristic of P. maculiventris over much of its range in north America. As most females would be mated in the fall, overwinter survival of males is less critical to the species and reduction of the male population would reduce intraspecies competition for prey in the following spring.

As is discussed in the conclusion of Chapter two, results of the experiments relating to the effects of temperature and light on development and the other parameters measured indicate that E. furcellata might be expected to complete 4 generations under climatic conditions of Quincy, Florida, while P. maculiventris should complete five. This advantage of the latter species is only partially offset by the higher fecundity of E. furcellata during mid summer. Thus on the basis of reproductive potential there is little reason to expect that E. furcellata can become established and much less that it could completitively displace P. maculiventris in north Florida. The reproductive advantage of P. maculiventris should diminish as monthly mean temperature increases toward the south and prospects for establishment of E. furcellata should be favorable in the Homestead area of south Florida.

An important part of this comparative study of E. furcellata and P. maculiventris was that of their efficacy as predators of a crop pest. Results of the field experiment at Quincy, Florida, failed to reveal any significant difference in the action of the two species in control of the velvetbean caterpillar in soybeans. However, mean yield of the plots into which the various stages and numbers of each species were placed on two dates was 280 gm more than the mean yield of the unsampled and sampled check plots. Calculations based on this difference in yield and the cost of producing and releasing the asopine nymphs show the per

hectare value of soybean protected to be $226.19 less than the cost of protection. However, this figure must be viewed in the light of costs of similar protection through use of insecticides. Figured on the basis of 3 applications (at $8.00 per acre) the cost of insecticide control would be $56.26 per hectare for the season. This deducted from $226.19 would lower the cost of control through release of the asopine nymphs to $166.93 per hectare (or $67.58 per acre). When hidden costs of insecticidal control such as induced secondary pests outbreaks, pest resurgence and development of resistance to insecticides as well as danger of excessive chemical residues are taken into account, the economics of control of velvetbean caterpillars through release of the predacious stinkbug nymphs looks much less unfavorable. To further improve the competitive position of the use of the predators there is the prospect of reduction in cost through efficiencies made possible by large scale production. Also, the effectiveness of released stock could be increased through additional research to determine optimum numbers and time of release. This information should be obtained before any attempt is made to test this method on a larger scale.

Of the other objectives of this research, the results of studies on prey species best suited for mass production of the asopine bugs showed none to be superior to larvae of the wax moth, G. mellonella. These could be reared most economically

on a diet already formulated for production of earthworms and crickets. Using this diet the cost in materials and labor for production of 1000 second to third instar nymphs was approximately 96 cents.

Limited laboratory and field observation indicated that while both E. furcellata and P. maculiventris appeared to be equally affected by egg parasitism by the scelionid, Trissolcus basalis, and to predation on first and second instars by big bugs, and damsel bugs, the larger instars were largely immune to this source of mortality. Dispersal of nymphs of both asopine species did not exceed 1.2 m. This indicated that their predacious activity can be expected to be concentrated in the immediate vicinity of the release site, and suggests that means should be devised to assure their release in as evenly dispersed manner as possible.

Finally, despite the release of more than 10,000 second and third instar E. furcellata nymphs in or near Gainesville during 1980, about 10,000 in 1981, and release of 3024 into the Quincy field plots in 1981, no adults were seen in 1982 that could be attributed to the 1980 and 81 releases. This is not conclusive evidence of failure to establish as the adults disappear soon after reaching maturity and undoubtedly disperse over a wide area. Assuming that females were able to find mates after they became sexually mature, the number of adult progeny produced would likely require

several generations before the widely dispersed population would build up to a readily detected level.

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BIOGRAPHICAL SKETCH

Jain-min Tseng was born in Wu-hau, Kwangtun, the Republic of China, on September 30, 1941. He received his secondary education at the Taiwan Provincial Pintung High School, Taiwan, graduating in July 1960. He received a Bachelor of Science degree in entomology from the National Chung-hsing University, Taichung, Taiwan, in June 1964. On passing the Taiwan Provincial Economic Civil Service Examination in July 1964, he was immediately appointed as Assistant Specialist in the Taiwan Provincial Food Bureau of the Taiwan Provincial Government. After serving one year as lieutenant in the army of the Republic of China, he joined the Taiwan Provincial Food Bureau in 1965 and began a program of insect pest management for stored food and rice insect control. From 1965 to 1968 he was also employed as a part-time high school instructor teaching mathematics, chemistry, and physical chemistry at Hau-chow High School and Taiwan Provincial Pintung Technical High School. On passing a selection examination in 1968, he was sent by the Taiwan Provincial Government to the Computer Program Training Class at the National Chiaotung University for 12-weeks training in computer programming. After passing the High Civil Service

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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